ACTA RADIOLOGICA

EDITA PER SOCIETATES RADIOLOGICAS
DANIÆ, FENNIÆ, NORVEGIÆ ET SUECIÆ

VOL. I FASC. 1 25 : VII 1921 N:o 1

Editorial

This journal which is now making its appearance before the world of science is the fruit of the collaboration between the associations of medical radiology in Denmark, Finland, Norway and Sweden. United as they are by a common culture and similar medical training, the radiologists of Scandinavia and Finland have decided to present the results of radiological research in their respective countries through the medium of their own journal.

The editors of ACTA RADIOLOGICA have been chosen by the radiological associations and the chief editor is elected by the other editors. Each country defrays its own expenses incurred for the publication of its own articles. Thus by joint work and joint economic responsibility the journal has the support of all the radiologists of the North.

Medical roentgenology as well as radiotherapy and heliotherapy stand on a high level in these countries which have associated themselves with ACTA RADIOLOGICA, and scientific research in these subjects is here in a promising state of development.

We possess well-equipped roentgenological departments at all our university clinics and at the big municipal hospitals, and these departments have their own chiefs who devote themselves entirely to radiology. New independent roentgenological departments are springing up year after year, and these are under the guidance of specialists. All hospitals have their own roentgenological laboratories.

Denmark is known all over the world as the cradle of heliotherapy and as being that country in which this science has attained the highest pitch of development through FINSEN's work and that of his followers. Sweden possesses a special hospital for the radiological treatment of cancer, in the shape of the Radium Home in Stockholm, and Lund University has also a special clinic for radiological therapy. The University Hospital »Rikshospitalet» in Norway has likewise a clinic for radiotherapy and heliotherapy, and a special hospital for the radiological treatment of cancer disease is being planned. In Copenhagen also a fully modern clinic for radiotherapy is under organisation, equipped by means of funds which have been supplied by public contribution and national grants. There is ***systematic instruction in medical radiology*** at most of our medical colleges.

But hitherto, however, an independent and special medium for the publication of our articles within the branch of medical radiology has been lacking. Our contributions have either been scattered in the special periodicals of other countries or else published in our home medical journals in which, in the majority of cases, they have been inaccessible to researchers from the foremost civilized countries on account of the difficulties encountered with regard to the comprehension of the Scandinavian languages.

We consider that the time is now ripe for collecting our work in a journal of our own. Medical radiology now stands at a very important stage of development. X-ray diagnostics and ray-therapy tend more and more to go separate ways. As a matter of fact, they make essentially different demands on the ***medical training*** of their operators, and the ***technique*** of their respective fields of activity develops more and more in different directions. ***X-ray diagnostics*** is, in reality, a ***branch of the macroscopial anatomy and pathology*** and X-ray diagnostics cannot attain a high degree of development unless its representatives possess scientific training in these fundamental medical disciplines. The science of the connection between the X-ray finding and the anatomical structure of the organism, i. e. »***X-ray anatomy***» opens up a vast field for research. The X-ray diagnostician must also, by close study, acquire a survey over the connection of the X-ray finding with other clinical symptoms.

Ray-therapy is still in its infancy, but this branch of the art of healing has, by exact methods of research, entered the field of science and it has already attained very auspicious results in several forms of disease. It employs physical forces which deeply interfere with the normal and pathological functions of the organism, and it therefore demands not only a sufficient knowledge of radiophysics, but also scientific apprenticeship in *physiology* and *pathology*, and a thorough knowledge of the *research methods of internal medicine* in those branches which come into touch with radiotherapy. In order to further develop his science, the radiotherapeutist must possess clinical training and have the opportunity of developing his science in his own clinic. At the same time, *radiophysics* is developing to a comprehensive science which it is impossible for a physician to master in a proper, scientific manner. Physicists have, therefore, been called ever more and more into the service of medical radiology and in all leading civilized countries there exist at certain radiological clinics scientific physical institutes.

Whilst ray-therapy as well as X-ray diagnostics are increasingly developing towards *specialisation*, yet, on the other hand, these special branches of medicine daily attain ever greater importance as *auxillary sciences* to most of the other branches of medical science. A large hospital already needs access to X-ray diagnostics as well as to radio therapy for most of its departments, and hospital doctors must have a corresponding opportunity of receiving an adequate training in these subjects and the possibility of following their development, in order to be enabled to rightly judge of the possibilities and limitations of the new science.

Radiotherapy, however, will scarcely become the general practitioner's property within a reasonably near future. But with the simplification which the technique of *X-ray diagnostics* has gradually arrived at, above all through the triumphal progress through the world of the *Coolidge tube*, the time should not be far distant when an X-ray equipment for less complicated examinations should be part and parcel of the equipment of a vast majority of medical practitioners. Before long the cost of providing a simple X-ray instrumentarium will not much exceed the cost of a first-class microscope and as far as practical importance for a doctor's diagnostical proficiency goes, be comparable with a micro-

scope. It will then, of course become necessary for those doctors who make use of the X-ray apparatus in their practice to carefully follow the development af X-ray diagnostics.

We trust that Acta radiologica will spur the Scandinavian radiologists on to take part in a friendly competition with each other in the great work of developing our science and that the journal will be of benefit to the numerous doctors who, although in no wise specialists within the sphere of medical radiology, yet, in their work, come into constant contact with X-ray diagnostics, radiotherapy and heliotherapy.

Acta radiologica will be published in volumes of about 500 pages, divided into 4 occasional numbers. Short articles are accepted for the journal itself, as a rule not exceeding 32 printed pages. More comprehensive contributions will be published as ***supplementary volumes*** to Acta and will be issued as detached works.

It is also our intention, as far as our resources allow, to leave space for ***articles by researchers from other countries*** as well. ***Reviews*** of important foreign works will also be given.

We have decided to publish the articles in Acta in the English, French or German languages, according to the choice of the author. We shall thereby reach not only the Scandinavian doctors who, as a rule, can read these languages quite freely, but also have the opportunity of introducing our work to the whole of the medical world.

In Acta radiologica scientists will find either in the original or in reviews all works of any importance within the field of medical radiology from Denmark, Finland, Norway and Sweden.

Gösta Forssell, M. D.

DE LA CLINIQUE RADIOLOGIQUE DU RIGSHOSPITAL, COPENHAGUE
CHEF DE LA CLINIQUE: DR H. J. PANNER

L'Examen radiologique de l'ulcère du duodénum

par

H. J. Panner

Quoique l'examen de l'estomac par les rayons X ait été très employé dans tout le monde civilisé pendant plusieurs années, ce n'est que pendant ces dernières années que cet examen est devenu plus répandu quant à l'ulcère du duodénum, où il est pourtant selon l'expérience très pratiquable.

Ce fait dépend de plusieurs causes, entre autres de l'importance prépondérante qu'on donnait autrefois, en examinant l'estomac, à la position vertical du malade, parce que l'estomac, après l'ingestion du repas bismuthé est ordinairement bien rempli dans cette position et un examen soigneux en peut facilement avoir lieu aussi bien par la radioscopie que par la radiographie.

Le passage du repas opaque se fait au contraire souvent si vite, qu'on n'arrive pas sans mesures spéciales à voir le bulbe du duodénum assez rempli. Mais à mesure que l'intérét pendant ces dernières années a été attiré plus fortement vers le développement clinique et le traitement de l'ulcère du duodénum, par les oeuvres des savants anglais et américains (Moynihan, Mayo), la technique de l'examen radiologique, en ce qui concerne cette souffrance, a subi de grands changements avantageux.

Pour éviter ce qu'on appelle le réflexe de MEHRING au pylore et pour chercher par ça à occasionner le duodénum de se remplir plus facilement et plus entièrement, HOLZKNECHT et KREUZFUCHS se servent d'un repas opaque, débourbé en eau (maintenant presque partout Sulphas baricus purissimus) et les Américains, suivants des raisonnements semblables, font usage d'une émulsion au lait de beurre, tandis que FORSSELL et son école se servent de son repas opaque ordinaire aussi pour l'examen du duodénum. La substance suspensoire pour la matière opaque introduite par FORSSELL (1908), est une crème presque liquide au sirop (préparée avec de la farine de pommes de terre) et servie chaude. On ajoute 300 grammes de cette crème en la remuant soigneusement à 125 grammes

de sulphate de barium, qu'elle tient bien suspendues. Je me suis aussi servi de ce repas opaque pour l'examen du duodénum.

Beaucoup plus considérable que les variations des modes de préparer le repas opaque est l'importance d'un examen plus sérieux que celui qu'on faisait ordinairement autrefois et non seulement le malade en position debout mais aussi en position couchée, sur le dos comme sur le ventre, éventuellement de côté ou de biais.

Tandis que quelques auteurs se servent seulement de l'examen radioscopique, la plupart d'entre nous sommes d'accord que cet examen ne suffit pas pour reproduire les détails fins essentiels et qu'il faut faire usage de la photographie et faire des images de diverses positions afin d'avoir pour comparaison réciproque et pour examen une série d'images. De l'autre côté la photographie ne suffit pas non plus. La radioscopie est une partie importante de l'examen, entre autres pour observer la fonction motrice de l'estomac. On peut même se servir facilement de quelques manipulations pour provoquer un arrêt prolongé du repas opaque dans le duodénum. On arrive souvent à faciliter le passage du contenu de l'estomac au duodénum par une expression manuelle et par une pression à la région duodéno-jéjunale on peut provoquer une stase dans le duodénum (Tab. I, fig. 3), ce qui aide à remplir celui-ci. Au lieu de comprimer la région duodéno-jéjunale avec la main, on peut se servir de la pelotte d'une ceinture à pression (Faulhaber) qu'on place facilement pendant la radioscopie à la place indiquée et dont les pièces métalliques quant à la pelotte consistent en aluminium (Forssell).

Après tout la technique de l'examen n'est point facile, elle demande du médecin comme du malade à la fois du temps et de la patience, et l'explication de la donnée radiologique suppose une expérience considérable.

*

Si l'on arrive à remplir le duodénum, cette portion de l'intestin aura dans des conditions normales une forme d'ombre caractéristique que l'on voit clairement chez les estomacs courbés. Ce n'est que la partie première, qui forme une ombre dense, ressemblant à une coiffe ou à une mitre, dont la base donne sur le pyrole tandis que l'apex, plus ou moins pointu, indique en haut et, ordinairement, un peu à droite. Souvent on voit l'orifice pylorique comme une étroite bande d'ombre qui joint le milieu de l'ombre ci-dessus décrite appellée le bulbe ou ***Bulbus duodéni*** (Holzknecht) à l'ombre de l'estomac. Chez les estomacs en travers le bulbe est souvent d'une autre forme, c'est à dire de celle d'un ovale en biais, plus ou moins distinctement séparé de l'ombre de l'estomac, dont la partie pylorique peut couvrir l'ombre du bulbe de sorte que

l'on voit à peine celui-ci. On arrivera alors à faire mieux apparaître les détails en tournant le malade de sorte que la radioscopie soit faite au diamètre en biais. Comme dit auparavant, les ombres du Pars descendens et du Pars inf. duodeni ne sont pas denses comme celle du bulbe, mais elles ressemblent à un boa de plumes dont les bandes d'ombre en travers correspondent aux espaces intermédiaires remplis du repas opaque entre les plis de Kerckring. On voit souvent sur le trajet de la Pars sup. à la Pars descendens une partie plus claire d'une grandeur variable venant d'une bulle d'air.

*

Les changements pathologiques, qu'on peut s'attendre à trouver à l'examen radiologique, sont des symptômes plus *indirects* ou plus *directs.*

Ces *premiers* symptômes (les indirects) sont en grande proportion causés par la relation, assurément très intime, entre les conditions du duodénum et les fonctions de l'estomac. C'est surtout ce fait qu'on observait auparavant avec attention quand il s'agissait de la radiologie du duodénum (Holzknecht, Kreuzfuchs, Schlesinger etc.) Schlesinger fait encore valoir avec force *la névrose de l'excitation* de l'estomac, qu'on trouve en cas d'ulcère du duodénum. Il prétend, qu'on ne trouve que très rarement un ulcère du duodénum qui soit »radiologiquement indifférent» quand même ce serait un ulcère tout à fait superficiel, car il veut dire, qu'un tel ulcère occasionnerait plutôt cette névrose que ne le ferait un ulcère de l'estomac. Les signes de la névrose de l'excitation sont d'abord une *hypersécrétion*, se montrant sur l'image radiologique comme une couche intermédiaire, plus ou moins élevée, entre la bulle d'air de l'estomac et le repas opaque, ensuite une »*hypertonie*», amenant une fonction peristaltique très prononcée et un estomac très contracté, qui prend souvent la forme d'un entonnoir, le corpus, étant étroit en bas et contrastant avec une partie large en haut, avec une bulle d'air large et basse. Des spasmes de l'estomac, plus ou moins éphémères, peuvent aussi être un signe de cette hypertonie. Un symptôme de la névrose est aussi le *hyperpéristaltisme,* se montrant à la radioscopie par le fait que les ondes péristaltiques commencent sur le corpus plus haut qu'à l'ordinaire, et qu'elles sont plus profondes et se suivent plus vite qu'elles ne le font normalement et qu'elles intéressent aussi la petite courbure beaucoup plus qu'à l'ordinaire. Cependant, en parlant de tous ces signes, il faut dire premièrement, qu'ils ne sont pas constants en cas d'ulcère du duodénum, et secondement que, lorsque on les observe, ils ne sont point caractéristiques en eux-mêmes pour ces ulcères-là. C'est qu'ils se présentent aussi avec

d'autres souffrances et justement avec celles dont la diagnose différentiale est très difficile quant aux ulcères du duodénum, c'est à dire en cas de hyperacidité, en cas d'ulcères de l'estomac dans la portion pylorique et en cas de calculs biliaires. À part cela il faut juger avec beaucoup de précaution surtout en présence d'une hypertonie et d'un hyperpéristaltisme.

La forme de l'estomac dépend de plusieurs facteurs importants au delà du tonus. L'architecture musculaire de l'estomac y joue probablement le rôle le plus important d'après ce que nous a montré FORSSELL par ses recherches anatomiques et radiologiques comparées. Quant à la force du péristaltisme il me semble souvent très difficile de déterminer, à quel degré elle tombe hors du cadre physiologique. Ici les explications subjectives auront facilement un grand jeu. D'ailleurs on a souvent à faire à des personnes nerveuses et, du reste, l'examen radiologique est toujours énervant aux malades, ce qui provoque des états qui peuvent sans doute influer le péristaltisme. Ainsi l'importance des symptômes dont j'ai parlé ne peut être que très limitée à moins qu'ils ne soient très distincts.

Tandis que les ulcères du pylore, même avec un péristaltisme actif, retardent ordinairement l'évacuation de l'estomac, les ulcères du duodénum présentent au contraire une évacuation rapide. Cependant il arrive quelquesfois qu'une évacuation rapide initiale est combinée à une évacuation retardée au total (une rétention de 4 heures, plus ou moins grande). Ce phénomène est observé surtout par KREUZFUCHS, qui l'a nommé »la motilité duodénale de l'estomac.» Il explique l'origine de cette mode d'évacuation par le fait que les ulcères duodénaux causent une sécrétion plus forte du duodénum et du pancréas (jamais prouvé) et à cause de l'augmentation de la sécrétion l'acide du suc gastric se trouve rapidement neutralisé, de sorte que le réflexe du pylore manquera. Le pylore devient alors insuffisant et le contenu de l'estomac s'écoule rapidement. Ce n'est que plus tard, pendant la digestion, que le suc gastric acide prédomine et que se produit un spasme tardif du pylore causant une rétention.

KREUZFUCHS lui-même nous a dit que ce mode d'évacuation se trouve également aussi avec d'autres souffrances, p. ex. avec les maladies de la vésicule biliaire, du pancréas, du coecum etc., ce qui fait que l'importance de cette diagnose ne peut pas être très grande.

Grâce aux travaux d'ALFR. MADSEN, de KN. FABER et de ses élèves, l'importance de l'épreuve de rétention clinique en usage après un repas d'essai (FABER-BOURGET) a été tirée au clair de sorte que l'épreuve de rétention radiologique devient à peu près inutile. C'est pourqnoi je n'y ai jamais attaché beaucoup d'importance. Si, ce que je trouve peu vraisemblable, l'on trouve que l'examen radiologique en cas de rétention

soit une meilleure ressource diagnostique que l'épreuve de rétention dont on se sert maintenant partout en Danemark, il faudra en faire usage.

Le dernier signe indirect d'un ulcère du duodénum — à mon avis sans grande importance — est l'existence d'un *point douloureux se manifestant à une pression localisée* nettement sur le trajet du duodénum. Quand même ce point douloureux suivrait le duodénum à son déplacément par la pression manuelle ou à cause d'un changement de position, les organes voisins se déplaceraient aussi avec le duodénum; les souffrances de ces organes, les maladies des voies biliaires, causent souvent une sensibilité à la pression exactement à cette place-là. Comme il s'agit souvent de trouver exactement les signes différents de la diagnostique des souffrances du duodénum et de ces autres organes, il me semble qu'en soi ce point douloureux à la pression n'a aucune valeur et que, combiné à d'autres symptômes plus importants, il est assez insignifiant.

*

En somme je pense qu'on peut dire que tous les signes indirects ci-nommés en cas d'ulcères du duodénum n'ont qu'une valeur diagnostique comparativement insignifiante.

Aussi, les efforts de ces dernières années ont eu pour but de rechercher par l'examen radiologique des *changements distincts, possibles à interpréter objectivement comme symptômes plus directs* de la présence d'un ulcère.

Ce sont surtout les *radiologistes américains* qui ont montré le chemin dans ce domaine avec une technique excellente (CASE, COLE, GEORGE, GERBER, LEONARD, CARMAN etc.), mais aussi les savants européens y ont travaillé avec diligence, ainsi outre *l'école viennoise* (HOLZKNECHT, HAUDEK, KREUZFUCHS), entre autres je nommerai STIERLIN, CHAOUL et SCHLESINGER. Ici en Scandinavie, en ce cas comme en plusieurs autres, ce sont FORSSELL et ses élèves, surtout ÅKERLUND, qui ont fait des travaux d'importance.

La portion du duodénum, dont la radiographie d'un ulcère doit présenter les plus grandes déformations, est le bulbe, parce que 95 % de tous les ulcères duodénaux se trouvent dans cette partie-là et parmi ces 95 % d'ulcères, 60 % sont placés à une distance du pylore ne dépassant $1\,{}^{1}/_{2}$ cm.

Sans doute quelques cas d'ulcère duodénaux causent une certaine insuffisance du pylore, suivie d'une rapide évacuation de l'estomac, ce qui occasionne quelques fois la formation d'un *grand bulbe duodénal.* Ce bulbe doit se former partiellement à cause de la forte pression con-

stante, qui vient de l'intérieur pendant l'évacuation, partiellement à cause d'une atonie de la musculature du bulbe, provoquée par des commotions nerveuses des fonctions, qui se rattachent à l'ulcère dans ce cas. L'image d'un grand bulbe constant est alors regardée d'être d'une certaine importance pour la diagnose des ulcères. On trouve cependant le grand bulbe avec d'autres souffrances de l'estomac, par exemple avec un ptose, une achylie, un cancer à son début, même avec une sténose du côlon, combinée à une stase de l'intestin grêle. En conséquence il ne faut pas attacher trop d'importance à l'ombre d'un grand bulbe, surtout si le cas en question ne présente pas en même temps une acidité normale ou une hyperacidité. (v. BERGMANN.)

Les déformations constantes de l'ombre du bulbe font un radiogramme caractéristique d'un ulcère duodénal et forment aussi la base solide pour la diagnose radiologique des ulcères ou des suites d'ulcères dans ce domaine. Ces déformations sont en différents cas très variables d'aspect et d'extension; quelquefois le contour naturellement rond de l'ombre bulbaire est un peu aplati ou replié, où paraissent des échancrures plus ou moins profondes embrassant des parties variables. Quelquefois on voit même que l'ombre du bulbe change jusqu'à prendre une forme lobée et rapiécée. Pour donner une importance diagnostique à la déformation, il faut que celle-ci soit constante pendant tout l'examen — la même projection posée —, éventuellement qu'elle persiste pendant des examens répétés. Si on ne voit pas chaque fois des images parfaitement identiques, il faut qu' on retrouve à diverses époques de l'examen certaines anomalies caractéristiques distinctes. On a dit que la diagnose d'une anomalie ne peut pas être émise après un examen radiologique, si seulement une des images montre un bulbe parfaitement normal. Ce n'est pas tout à fait exact. Je pense qu'il faut donner raison à SCHLESINGER, qui prétend que dans ce cas la position du malade et la place de l'ulcère ne sont pas indifférentes, et qu'on trouvera dans un certain cas un changement du bulbe dans une position mais pas dans une autre, et j'ai fait cette expérience moi-même dans des cas isolés. La règle générale est cependant, comme je l'ai dit auparavant, qu'une ombre bulbaire normale, une fois trouvée, donne un résultat négatif de la diagnose radiologique.

En cherchant de plus près la cause de ces déformations du bulbe on partait au commencement tout naturellement de la théorie que c'étaient en partie l'ulcus même ou des changes cicatricielles après un ulcus, partiellement des adhérences périduodénales, qui formaient le substrat pathologique-anatomique des déformations. On constatait cependant très souvent aux opérations un manque de rapport entre le radiogramme et l'état véritable des choses, même quand la présence d'un ulcus fut constatée, ce qui est en réalité la même chose que ce qui arrive avec un Ulcus corporis

ventriculi d'un estomac en forme de sablier, où l'opération ne fait presque jamais voir de si grandes anomalies que le radiogramme, dont l'aspect dépend plus ou moins des états spastiques. Plusieurs auteurs, Schlesinger, Carman, et surtout Åkerlund, ont beaucoup accentué qu'en analogie avec les conditions d'un ulcère de l'estomac, ce sont des spasmes qui jouent un grand rôle au changement du bulbe en cas d'ulcères duodénaux et que *ce changement dépend souvent entièrement des conditions spastiques.*

Selon le siège et l'étendue de l'ulcère (le spasme), la déformation peut varier beaucoup; on trouve souvent une défiguration dont les signes caractéristiques sont accentués par Åkerlund. Il les a trouvés lui-même plusieurs fois et aussi dans des publications d'autres auteurs, quoique ceux-ci, à son avis, n'ont pas reconnu eux-mêmes le point typique de leurs images.

Dans la plupart de mes cas la défiguration a été de ce type ce que prouvent les figures ci-jointes. Åkerlund explique ainsi l'origine de la forme d'ombre en question: le siège de l'ulcère duodénal est souvent tout près du côté de la petite courbure; il se fait alors voir ici soit par une contraction spastique, soit à cause des anomalies cicatricielles, un aplatissement du contour normalement convexe de l'ombre bulbaire du côté médial et un effacement de l'angle proximal et médial du bulbe. Comme cela *l'orifice pylorique* (Fig. 3. Tab. I.) s'il est rempli, prend une situation *excentrique* vis-à-vis de l'ombre bulbaire vers le centre de laquelle elle est dirigée normalement. On voit en même temps du côté de la grande courbure un défaut du bulbe plus ou moins grand et plus ou moins profond, d'une forme ségmentaire, (Fig. 3. Tab. I) qui s'étend sur l'ombre bulbaire jusqu'à ce qu'il n'en reste plus qu'une bande d'ombre étroite le long du côté aplati de la petite courbure. Parfois on trouve du côté aplati médial une [ou deux] proéminence plus ou moins distincte, (Fig. 4. Tab. I) et nous avons là — en miniature — tout à fait la même image que nous rencontrons souvent en cas d'ulcus corporis ventriculi c'est à dire une *niche, correspondant à l'ulcère* [pénétrant] et un rétrécissement, opposé à celui-ci, un rétrécissement, qui dépend le plus souvent, comme celui des ulcères de l'estomac, d'un spasme. Pour prouver l'exactitude de cette explication, Åkerlund nous dit *que* dans plusieurs cas, où par l'examen radiologique, il a démontré ce type de défiguration, l'opération a vérifié la présence d'un ulcus duodénal, mais à part cela aucun changement de la forme du duodénum qui pourrait correspondre à l'image radiologique, et *que* par un traitement interne, l'échancrure a dans plusieurs cas disparu simultanément avec la guèrison clinique. D'après les figures ci-jointes on voit les grandes variations des déformations, mais on en voit aussi distinctement les signes communs caractéristiques.

ÅKERLUND est aussi d'avis qu'on peut expliquer »la motilité duodénale de l'estomac» par le spasme du duodénum en supposant que simultanément avec spasme circulaire un spasme de la musculature longitudinale se présente qui empêche le pylore de se fermer, ce qui produit une insuffisance pylorique avec une évacuation rapide. À mesure du progrès de la digestion de l'estomac le spasme peut se fortifier et la contraction circulaire peut devenir si forte qu'elle retarde la fin de l'évacuation de l'estomac. L'arrêt ne dépend donc pas, comme dit HAUDEK d'un »spasme tardif» du pylore. Aussi bien l'évacuation rapide initiale que la rétention de 4 heures, quand même présente, sont expliquées par la même cause, c'est à dire par le spasme duodénal. Cette explication est très ingénieuse, mais elle n'est guère tout à fait suffisante. On verrait en ce cas une diminution progressive de la raie d'ombre à mesure que progresse l'évacuation de l'estomac, ce qui n'a pas lieu. Il est plus vraisemblable, que l'estomac commence par se vider rapidement mais se relâche peu à peu, peut-être à cause de l'insuffisance du pylore en suite d'un spasme de la musculature longitudinale, comme le suppose ÅKERLUND. À cause de l'atonie ainsi déterminée le pylore se débarrasse difficilement du dernier reste de son contenu.

Sauf les spasmes du duodénum, les ulcères duodénaux peuvent causer des spasmes de l'estomac ressemblant à ceux qu'on voit en cas d'ulcères de l'estomac. Des »*spasmes éloignés*», de ce genre, sont décrits par plusieurs auteurs (BARON et BARSONY, CASE, ÅKERLUND); de ces spasmes, il y en a de constants et d'intermittents, ils changent en certains cas et peuvent devenir plus profonds à la suite d'une pression sur le duodénum! Dans plusieurs cas d'ulcères duodénaux reconnus définitifs ÅKERLUND prétend avoir vu paraître de tels spasmes par une pression sur le siège de l'ulcère qui disparaissent au moment où cesse la pression.

*

CHAOUL et STIERLIN nomment comme signes pathognomoniques des ulcères duodénaux ce qu'on appelle les »prolongements du pylore», c'est à dire des formes d'ombre irrégulières d'une grandeur variable qui sortent du pylore et s'étendent dans le domaine duodénal. Je n'en fais aucune description spéciale car il me semble qu'ils ne sont que des déformations bulbaires déterminées ou par des spasmes ou par des anomalies cicatricielles, ou par une combinaison de ces deux phénomènes.

On pourrait dire la même chose de ce qu'on appelle »*les taches duodénales persistantes:*» des taches d'ombre plus ou moins grandes se présentant dans la région du bulbe. On les trouve aussi bien quand l'estomac contient du bismuth qu'après l'évacuation de l'estomac, et on

les trouve aussi soit combinées à un bulbe déformé, soit séparées du bulbe. Elles sont d'origine variable. Quelquefois ces taches sont déterminées par des dépôts de bismuth enfermés dans des parties du bulbe, étranglées par des spasmes ou par des anomalies cicatricielles; elles représentent rarement les ulcus pénétrants eux-mêmes et représentent alors les *vraies niches de* HAUDEK, qu'on trouve en tout cas indiscutablement plus souvent en cas d'ulcères de l'estomac qu'en cas d'ulcères duodénaux.

★

En trouvant une déformation de l'ombre du duodénum on se demande naturellement, si elle ne peut pas dépendre d'autres souffrances que d'un ulcère duodénal. La réponse doit être affirmative. Sans doute les déformations de l'ombre du bulbe, soit par des spasmes, soit par des inflammations adhésives, peuvent être déterminées par les souffrances d'autres organes, surtout des voies biliaires. Dans le plus grand nombre des cas ces déformations sont causées cependant par des ulcères duodénaux. Il faut donc que le jugement définitif de la diagnose se fasse en combinant les autres signes cliniques au résultat radiologique.

On se demande ensuite, si les anomalies ci-dessus décrites sont fréquentes. J'ai observé en 18 mois 35 cas pour lesquels, après l'examen radiologique j'ai cru devoir faire la diagnose d'un ulcus duodéni. Dans 6 cas seulement ces malades ont été opérés. 4 fois la diagnose d'un ulcus fut vérifiée; dans l'ún des cas la lésion était un ulcère pylorique avec des adhérences autour du pylore; un des malades n'avait point d'ulcus mais des adhérences entre le duodénum et la vésicule biliaire qui ne contenait pas de concréments, et enfin, dans un cas, pour lequel mon diagnostic était très incertain, aucune anomalie n'a été trouvée.

Jugeant d'après ces quelques cas opérés, je crois qu'une étude exacte des images radiologiques (de la nature des déformations) combinée aux données autoptiques futures, aidera à éviter les erreurs diagnostiques. D'autre part je pense aussi, que les ulcères duodénaux — comme c'est le cas avec les ulcères de l'estomac — échappent souvent à l'observation lors de l'examen radiologique, celui-ci montrant des conditions parfaitement normales de l'estomac et du duodénum.

Explication des figures

V. L'ombre de l'estomac. P. Le pylore. Pl. L'excentrique orifice pylorique. I. Une échancrure (spasme) de l'ombre du bulbe. N. Une niche (?). Dd. Pars descendens duodéni. T. L'ombre des intestins grêles.

Sur les figures 2 et 3 on voit en bas l'ombre des doigts gantés en cautchouc-plombé de l'examinateur. Les figures 3 et 4 présentent le même malade avec et sans compression dactyle.

Resumé

L'auteur présente une exposée critique des signes radiologiques directs et indirects de l'ulcère de duodénum.

Les examens radiologiques du duodénum se font nécessairement non seulement le malade se trouvant en position debout, mais aussi en position couchée du malade (position dorsale, ventrale et latérale).

Il faut prendre garde de ne pas attacher trop d'importance aux symptômes indirects.

Les symptômes directs, la déformation de l'ombre bulbaire et surtout le type d'ÅKERLUND, sont les meilleurs signes caractéristiques de la diagnose radiologique et ceux-ci ne provoqueront guère des erreurs diagnostiques, mais la technique nécessaire pour les faire paraître demande une grande expérience et beaucoup de patience.

Fig. 1.

Fig. 2.

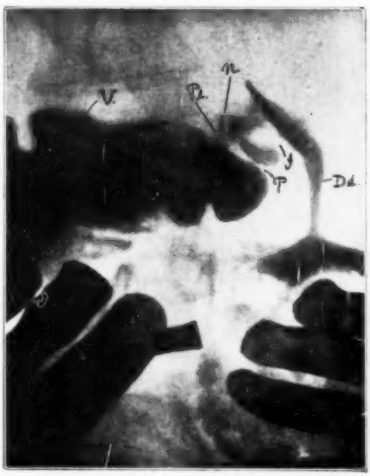


Fig. 3.

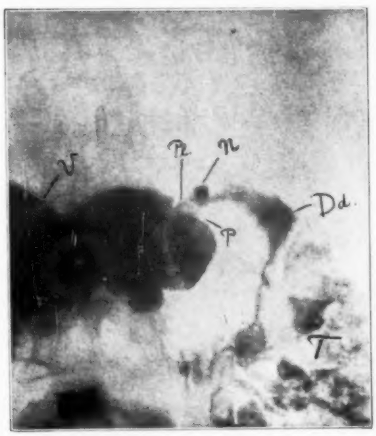


Fig. 4.

On the X-ray Diagnosis of Gallstones in the Common Duct

by
M. Simon, M. D., Stockholm

(Tabula II. Figs. 1 and 2)

May 19:th, 1920, a man, 62 years old, who had suffered from repeated attacks of Icterus and fever without any pains, was sent me for X-ray examination. Cholelithiasis was suspected, but the diagnosis was quite unsure.

The fluoroscopic and radiographic examination of the stomach in all the usual positions did not reveal anything pathological. The duodenal bulb showed at its right border an impression of that type which is described as caused by a dilatated gallbladder.

A shadow of the size and form of a goose-egg corresponded most probably to the bladder itself (Fig. 2. Tab. III); (other shadows were recognized as belonging to the liver and to the right kidney).

No concrement-shadows were visible. As the patient was very fat, there was no possibility to obtain a plate, which with evidence could show stones of a very low density.

Fortunately there was another way to get an X-ray diagnosis of stone: two plates in the prone position showed a *sharply outlined, complete defect in the Barium-shadow of the descendent part of duodenum*, a defect *of oval form*, the size of 10 × 15 mm. (Fig. 3. Tab. III). This plate shows the bulb contracted; in duodenum Barium only round the defect. No distinct tenderness in that region.

The defect is localized at the supposed place of Papilla Vateri. A »residual shadow» 4 $^1/_2$ hours after the Barium-meal corresponds in form and place with the Bariumshadow at the upper left border of the defect.

Regarding the clinical history, the form and place of the defect in the duodenal shadow, I thought there was sufficient reason for making the almost sure diagnosis: »*Big gallstone, fixed in the papilla Vateri or in its immediate neighbourhood.*»

At a new examination, Oct. 6:th, nothing had changed, except that the defect this time was not surrounded on all sides by Barium; the foreign body made an impression only at the left border of the duodenum. A month later an operation was performed by Dr RISSLER: *in the common duct immediately above the Papilla was found a concrement of nearly the same size as the duodenal defect.* It was so soft, that it went into pieces at the slight pressure of the fingers. The gallbladder was distended as shown by the pictures.

In going through the Röntgenological literature, I have found no previous case with a rœntgen-picture, similar to the above described. Those X-Ray-diagnosticised stones in the bileducts, that were demonstrated in the Medical Societies or are otherwise published, seem all to have been found as shadows of a greater density than the surrounding tissues. (BECK, PFAHLER, CASE, FORSSELL, ASSMANN, LÜDIN, KNOX and others.) Perhaps a case as mine would not be so rare, if the rœntgenologists more generally accepted the »custom of combining the Bariummeal with the Röntgenographic examination in all suspected cases of gallstones» as suggested by CASE. (International Clinics, Vol. 4, Series 25. 1915). However, I am convinced that in those cases special plates of the region of the gallbladder must be taken *before* the Bariummeal.

Summary

Case with autoptically controlled gallstone in the lower end of the common duct, Roentgenologically not directly visible as a positive shadow, but as a defect in the Ba- filled duodenum. In the prone position the stone made an impression in the intestinal wall immediately above the Papilla Vateri.

VON DER CHIRURGISCHEN ABTEILUNG DES KINDERKRANKENHAUSES IN GOTHENBURG
OBERARZT DR. SVEN JOHANSSON

Ein Fall von Osteogenesis imperfecta mit verbreiteten Gefässverkalkungen

von

Sven Johansson

(Tabula II Fig. 3 und Tabula III)

Die oben erwähnte Krankheit ist zwar bei weitem nicht gewöhnlich, ich würde doch nicht einen einzigen Fall als beschreibenswert ansehen, besonders nicht da dieser Fall nicht zu dem Klarlegen der Aetiologie geeignet ist, wenn nicht der fragliche Fall in gewissen Beziehungen sehr eigenartig wäre, ja, so viel ich von der Litteratur gesehen habe, vollständig unik. *Krankengeschichte und übrige Befunde* sind kurz folgende: N:r 255/1916. P. L. Knabe, 6 Tage alt.

Erblich ist nichts von Interesse. In der Anamnese der Eltern giebt es nichts, dass auf Lues deuten könnte. Der Knabe ist etwas zu früh geboren. Gewicht bei der Geburt c:a 2 Kg. *Ein paar Tage nach der*

Fig. 1.

Geburt wurde konstatiert, dass der eine Humerus frakturiert war, weshalb das Kind in das Krankenhaus eingenommen wurde.

Status beim Einkommen: Das Kind ist ein venig atrofisch. Gewicht 2280 Gr. Das allgemeine Aussehen des Kindes geht übrigens aus dem Bilde 1 hervor. *Beide Humeri sind frakturiert.* Wasserman neg. Rönt-

genphoto einige Tage nach der Ankunft giebt folgendes an die Hand: Das *Cranium:* Die Basis des Schädels wie der Ober-und Unterkiefer geben deutlichen Knochenschatten. Im übrigen giebt es nur ein schwaches Andeuten an Ossifikation in der Form von mosaikenartig angeordneten kleinen Knochenplatten, die am deutlichsten auf dem Gebiete der Ossa parietalia und des Os occipetale hervortreten.

Die oberen Extremitäten: keine Epiphysenkerne. Die Knochen sind arm an Kalk; die Kortikalis ist dünn mit scharfer Kontur; die Spongiosa ohne Struktur; Fraktur der beiden Humeri nahe der proximalen Enden derselben; Fraktur des rechten Radius.

Fig. 2.

Die unteren Extremitäten: Knochenkerne in der unteren Femur- und der oberen Tibiaepiphyse.

Die Epiphysenlinien sind gerade.

Die beiden oberen Femurenden zeigen Frakturen, ebenso das rechte untere Femurende gerade oberhalb der Epiphysenlinie. Die linke Tibia ist sowohl unten wie oben frakturiert. Ausserdem sind mindestens 2 Rippen gebrochen. Sonst nichts besonders bemerkenswert am Röntgenbilde.

Während des Aufenthaltes im Krankenhause wurde der Zustand des Kindes ohne nachweisbare Komplikationen immer schlimmer, obwohl das Kind von der Mutter ernährt wurde. Das Gewicht sank allmählich von 2 280 Gr. zu 1 800 Gr. Die Atrophie nahm zu. (Fig. 2). Die ganze Zeit war die Temperatur subnormal, während längerer Zeit c:a 35° C und ein paar mal 33.3° C (!). Mors c:a 3 Monate nach der Ankunft.

Die Sektion zeigte eine Gehirnblutung in dem rechten Temporallobus. *Die Thyreoidea und das Thymus sind auffallend klein.* Im übrigen nichts besonders bemerkenswertes. Das Aussehen post mortem geht aus dem Bilde 2 hervor.

Röntgenphoto post mortem zeigt folgendes:

Das Cranium: Keine augenfällige Veränderung im Vergleich mit dem vorigen Bilde.

Die oberen Extremitäten: Die eine Humerusfraktur ist geheilt, bei der anderen hat die Heilung angefangen, doch mit sehr geringer Callusbildung. Die Radiusfraktur ist geheilt. Die Corticalis ist dünn und scharf gezeichnet; anfangende Spongiosazeichung. Auf der rechten Seite sieht man einen kleinen Knochenkern in der oberen Humerusepiphyse. *Am rechten Arm tritt sowohl am Ober- wie am Unterarm deutlich ein leicht geschlungenes Gefäss hervor (Arteria brachialis und radialis.)* Fig. 3. Tab. II.

Die unteren Extremitäten: Auch hier sind die Frakturen geheilt. Das linke obere Femurende ist stark aufgetrieben. Distinkte, gerade Epiphysenlinien. *An beiden Beinen (besonders am linken) tritt deutlich ein leicht gewundenes grosses Gefäss hervor, sowohl am Oberschenkel wie am Unterbein (Arteria femoralis und tibialis).* Fig. 1. Tab. III. Die Unterbeine sind stark gekrümmt. Ausserdem nichts bemerkenswertes, wenn nicht ein paar geheilte Rippenfrakturen.

Mikroskopische Untersuchung der Weichteile der Fossa poplitea: Auf dem Schnitt Muskulatur, Nerven, Artären und Venen. Hyperplasie der Intima der sämtlichen grossen und mittelgrossen Artären. In den mittelgrossen Artären ist die Hyperplasie von konzentrischem Typus und die Media unverändert. In den grössten Artären ist die Intimaverdickung zu der einen Seite der Gefässwand lokalisiert. Die Media ist hier in grosser Ausdehnung zerstört, das Gewebe von grossen Kalkschollen ersetzt. Die Elastica intimae, ebenso kalkincrustiert, scheint die degenerativen Veränderungen gegen das Gefässlumen abzugrenzen. Die Mediazerstörung ist am meisten auf dem Gebiete ausgesprochen, welches der stärksten Intimaverdickung entspricht. Die Wände der Venen zeigen keine Veränderungen. Das Gevebe der Gefässwände im übrigen befindet sich in einem ziemlich embryonalen Stadium mit geringer Differentierung. (Dr. G. ODELBERG-JONSON.)

Epikrise: Es ist kaum möglich zu bezweifeln, dass der hier vorliegende Fall zu der heutzutage sowohl klinisch wie pathologisch-anatomisch gut abgegrenzten Krankheitsgruppe gezählt werden muss, welche Osteogenesis imperfecta genannt wird. Das allgemeine Aussehen, der klinische Verlauf, die Röntgenbilder, alles spricht dafür. Denjenigen, welcher vielleicht nicht diese Arbeit kennt, möchte ich in diesem Zusammenhang auf die ausgezeichnete Monographie von FRANGENHEIM hinweisen, über »Die Krankheiten des Knochensystems im Kindesalter» (Neue Deutsche Chirurgie, Bd 10), und kann, wenn ich hierauf hinweise, von weiterem Räsonnieren betreffs der Differentialdiagnose etz. abstehen. Was in

diesem Falle besonders anmerkungswert ist und was mich auch veranlasst hat denselben zu publizieren, ist das Vorkommen von Kalk in den Gefässen und dieses in so grosser Menge, dass die Gefässe deutlich auf dem Röntgenbilde hervortreten.

Wie interessant es auch wäre die Frage von der Pathogenese zur Diskussion aufzunehmen und besonders die Ursache zu der Kalkeinlagerung in den Gefässen, zu dem Mangel an Kalk im Skelett in Parietät gestellt, muss ich doch davon abstehen; hierzu wären viel mehr eingehende histologische Untersuchungen von Nöten, als diejenige zu dessen Ausführen ich Gelegenheit gehabt habe. Ich möchte es doch nicht unterlassen diesen Fall denjenigen mitzuteilen die mit der Lösung solcher Probleme beschäftigt sind. Die geringe Entwickelung der Thyreoidea und des Thymus muss notiert werden. Frühere Forscher haben keine Veränderungen in diesen Organen nachweisen können, die mit der Krankheit in pathogenetischem Zusammenhang gesetzt werden konnten. Die Gehirnblutung, die wohl die nächste Todesursache war, muss nicht auf das Konto der Gefässveränderungen geschrieben werden, wenn auch solche im Gehirn vorhanden waren, welches leider nicht untersucht worden ist; man hat nähmlich bei Osteogenesis imperfecta ziemlich oft Gehirnblutungen gesehen, welche ganz genügend von den unvollständigen Ossifikation der Kranialknochen erklärt werden sowie durch das damit in Verbindung stehende Unvermögen gegen Traumata zu schützen.

Das Verhältnis, dass die Gefässveränderungen nicht auf dem ersten Röntgenbilde nachweisbar waren, darf nicht so gedeutet werden, als seien dieselben damals nicht vorhanden, sondern beruht gewiss auf die bei dieser Gelegenheit weniger scharf gezeichneten Bilder.

Zusammenfassung

Verf. beschreibt einen Fall von Osteogenesis imperfecta mit multiplen Frakturen, welcher von besonderem Interesse ist, weil die Arterien sowohl der oberen wie der unteren Extremitäten auf den R. bildern deutlich hervortretende arterioscleriotische Veränderungen zeigen. Histologische Untersuchungen zeigten Degeneration und Kalkinkrustationen der Intima und Media der Arterien. Gl. Thyreoidea und Thymus auffallend klein. Kein ähnlicher Fall ist, so viel der Verf. weiss, beschrieben worden.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 1.

A Case of Arthropatia Psoriatica

by

S. Ström, M. D., Stockholm

(Tabula IV)

It has long been known that psoriasis is occasionally found in combination with affections of the joints, and in general these have been regarded as a complication directly connected with the dermatosis. This special affection of the joints is, as a rule, polyarticular; it is characterized in an eminent degree by a chronic course without any tendency to valvular heart complication; it is not affected by salicyl administration, and it leads, at an early stage, to general malformation and destruction of the joints (ADRIAN). The disease is, however, comparatively rare and the roentgen literature contains, so far as I have found, only a few roentgenograms of it. I have pleasure in contributing the following case to the roentgen picture of this peculiar arthropaty.

The patient is a man of 50, who has had psoriasis since the age of 20. He has been treated by a skin specialist for a several years with arsenic and chrysarobin, and has improved, but never become quite free from the skin disease. At about the age of 28 the patient noticed in the nails of the thumb and great toe alterations in the form of small brown spots. The nails gradually thickened, and depressions and ridges appeared in them. At the same time the great toe began to swell, so that the patient had difficulty in wearing shoes. Some years later, the joint of the left thumb and the distal joint of the little finger also began to swell. This swelling in the toe and finger joints has remained ever since, and the toes and fingers have gradually become shorter. The patient has not had any real pains in his joints. Of late years, however, he has felt a certain discomfort in one knee and in the wrists, and as he was afraid that the affection of the joints might extend to these parts also, he consulted an internal specialist. The latter found increased blood-pressure, and, suspecting luetic alterations of the bones, he sent him to me for roentgen examination.

Roentgen findings. Fig. 1 is a general view of his two hands, fig. 2 is a frontal picture of the thumbs. In the left hand we see in the thumb a complete destruction of the basal portion and corpus of the terminal phalanx, of which only tuberositas unguicularis remains. This remainder of the terminal phalanx, however, lies close up to the capitulum of the proximal phalanx, forming with it a sort of joint. The whole thumb is thus, as appears, considerably shortened. The capitulum of the proximal phalanx exhibits destructions in the lateral surfaces and in the articular surface, which is almost saddle-shaped. In the general view-picture the sesamoid bone of the metacarpal-phalangeal joint in the left thumb is considerably enlarged, being about three times as large as the corresponding bone on the right side, and it is somewhat irregular in form. This joint exhibits otherwise no alteration with the exception of a slight roughness in the volar edge of the proximal phalanx.

The little finger of the same hand shows alterations resembling those in the thumb, although the destruction is not quite so great. The small remainder of the terminal phalanx is in an oblique line to the middle phalanx, the capitulum of which has an oblique surface on account of bone destruction.

In the terminal phalanx of the right thumb are to be found small, sharply-defined rarefications at the base of the phalanx, and the articular cartilage in the interphalangeal joint is reduced in height. As shown by the frontal picture some small spurs are found in some places. This picture thus reminds one of a chronic osteoarthritis.

Fig. 3 and 4 are roentgenograms of the two feet. We see in both great toes a destruction of the terminal phalanx, of which only the base and part of tuberositas unguicularis remain, separated from each other. The remnant of the base shows some rounded, sharply defined thin spots within the bone, most marked in the right toe (Fig. 4). Here also the head of the proximal phalanx is deformed on the medial side. Some small, thin areas are also found in the head. The articular cartilage in the joints is reduced.

In the other toes of both feet is found a small piece of bone in the distal portion of the toe; this is all that is left of the middle and terminal phalanges. The proximal phalanges exhibit a characteristic change. The diafysis portion of the phalanges in the left foot (Fig. 3) is atrophic and narrow, tapering off towards the distal end, and the head in all of these is to a great extent destroyed. In the second toe only a small remnant of the head is left, and this is separated from the rest of the bone. In the right foot (Fig. 4) the proximal phalanges are considerably longer, their diafysis portion, especially in the three lateral toes, is narrower than usual, and rarefications in the side contours and the articular surfaces have given a peculiar form to the head in all of the toes.

As well as the fingers and toes, which plainly exhibited external changes, I have also photographed the patients two carpus with the adjacent part of the underarm, and the left knee. The only noteworthy feature in the carpus is a central thinspot in one os hamatum, probably a structural anomaly.

In the upper jaw two incisors and one praemolar (permanent teeth) have atrophied roots, without granuloma formation.

Clinical observations. A man of ordinary constitution, general condition good. Nothing remarkable about internal organs. The nerve system shows no pronounced disturbances, only the sense of contact and pain somewhat diminished in the fingers and toes. W. R. neg.

The cornea of one eye is infiltered after iritis some years ago with increased pressure and secondary keratitis. (Dr. Setterquist).

The external configuration of the hands is partially evident from the roentgenograms. In the affected joints of the left thumb and little finger, which exhibit shortening and an indolent swelling, there is no active mobility, but a certain degree of a passive one. In the interphalangeal joint of the left thumb there is, however, a certain slight active mobility.

In the feet the distal portion of the toes exhibits diffuse swelling. There is neither active nor passive mobility in the interphalangeal joint of the great toes. On the other hand, the interphalangeal joints of the other toes are quite limp.

The nails of the affected fingers and toes show considerable changes; they are greatly thickened and fluted and are partially loosened from the nail-bed. The nails of the great toes form horny lumps of a good 5 mm in thickness and are completely deformed.

The skin changes are limited to the head and back. Over the greater part of the scalp are to be found rounded, partially confluent psoriatic efflorescenses, overlaid with brittle, yellowish-white crusts. On the back are to be found three plaques, two of which are large, measuring about 2×3 cm. in diameter. All the skin changes have the typical appearance of psoriasis with vivid red or red-brown, scaly plaques. The skin in general is of ordinary thickness and shows no sign of sclerodermia.

Roentgen literature on psoriatic affections of the joints seems to be very scanty. In the literature at my disposal the only roentgen pictures I have found reproduced have been in a paper by Ledoux-Lebard on the various kinds of ankylosis. These pictures show psoriatic arthropathy in the hands in different stages. Following BÉLOT, who is said to have treated the disease in more detail, he distinguishes four different stages in this ankylosating process.

1re phase: Diminution de l'interligne articulaire et début de la raréfaction osseuse (phase prémonitoire).

2e phase: Raréfaction osseuse prononcée, allant par place jusqu' à la disparition du tissu osseuse (phase déstructive).

3e phase: Des néoformations osseuses apparaissent par place et tendent à réédifier du tissu osseux (phase hyperplasique). Elles sont habituellement désordonnées et aboutissent à la

4e phase: Formation de soudures osseuses, constitution de l'ankylose (phase de l'ankylose).

We find these stages partly reproduced in the roentgen pictures above, although advanced destructive changes predominate here. But we see not merely alterations in the joints: the destructive changes often extend beyond the region of the joints, leaving only small bone fragments of some of the phalanges, while other phalanges exhibit an atrophic narrowing. The hypertrophic changes are fairly insignificant.

This roentgen picture of bone alterations in fingers and toes reminds one somewhat of the skeleton changes which have been found in cases of vasomotoric-trophic neuroses, such as sclerodermia and morbus Raynaud, also of the skeleton changes in certain nervous disorders, specially syringomyelia and lepra nervorum. NEUBERT has published a case of sclerodermia, in which he found atrophic bone processes combined with hypertrophic, together with destructions in both wrists and breaking down of a number of bones. CASSIRER, in his paper on the vasomotoric-trophic neuroses, gives a picture of a case of »sclérodermie en plaques» with atrophic changes in the phalanges of the toes and destruction in a number of joints, which reminds one of the case here published. Similar rarefying processes in the phalanges can also occur in morbus Raynaud, but rarely alterations in the joints. Skeleton changes in syringomyelia are usually, in about 80 % of the cases, confined to the upper extremities. Sometimes there is a more or less complete destruction of a great joint, as, for instance, the shoulder joint, while in other cases mutilating processes occur in the fingers and toes, accompanied by suppurations. In lepra nervorum, finally, destructive and atrophic bone processes occur in the hand and foot skeletons, but the changes have often, like as in syringomyelia, a multilating character and are not especially localized to the joints. The resemblance between any roentgenograms of lepra, published by DEYCKE PASCHA, and the pictures given above is, however, both striking and interesting.

As is well known, there is great diversity of opinion regarding the etiology of psoriasis. According to RIECKE the four principal views of the subject are:

1) Psoriasis is of arthritic or herpetic origin.
2) It is of neuropathic nature.
3) It is a constitutional anomaly.

1. Left and right hand.

Fig. 2. Both thumbs.

Fig. 3. Left foot.

Fig. 4. Right foot.

4) It is a parasitic disease.

Opinions 2 and 4 have especially won support, though no certain proof has been adduced for either the one or the other. Recently, however, a German author (BROCK) has pronounced the opinion, that psoriasis is caused by a disturbance of internal secretion. He founds his theory on the statement that in several cases he obtained a cure or improvement in the skin disease by the application of a small roentgen dose (»stimulus dose») to the thymus. How far this theory is correct can only be shown by continued experiments with this method of treatment. At any rate, there does not seem to be any resemblance between the skeleton changes with which we are acquainted in the various kinds of disturbances of the internal secretion and those in arthropatia psoriatica. As has been pointed out above, this affection seems, as regards the roentgen picture, to stand in the nearest relation to some affections of neurogenic nature.

Summary

A case of arthropatia psoriatica with advanced destructive and atrophic changes of bones and joints in fingers and toes. The case indicates the affinity of the affection with bony changes of neurogenic nature.

Bibliography

BROCK: Strahlenterapie. Bd. XI, H. 2.

CASSIRER: Die vasomotor. tropischen Neurosen. Berlin. S. Karger 1912.

DEYCKE-PASCHA: Knochenveränderungen bei Lepra nervorum im Röntgenbilde. Fortschr. a. d. Geb. d. Röntgenstrahlen. Bd. IX.

FÜRNROHR: Die Röntgenuntersuchung in der Neurologie. Rieder u. Rosenthals Lehrbuch der Röntgenologie, Bd. II, 1918.

HAENISCH: Röntgenbild der Hand eines vorgeschnittenen Falles von Syringomyeli. Cit. in Fortschr. Bd. X. P. 248.

JACOBAEUS: Ett fall av Lepra anaestetica. Hygiea, Festband, 1908.

LEDOUX-LEBARD: Radiodiagnostic, radiothérapie et radium-thérapie des ankyloses. Journ. de radiol. et d'électrolog. Tome I. P. 217.

MACHADO: Trophische Störungen bei Raynaudscher Krankheit. Fortschr. Bd. 18.

LLOYD-BRYAN: Bony changes in feet, following fracture of the vertebrae. — Amer. Journ. of roentgenol. Vol. VII. N:o 3.

SCADUTO: Radiogramme d'un cas d'arthropatie symmétrique des extrémités, (syringomyeli). La radiol. medica, 1918, IV cit. in Journ. de radiol. et d'électrologie. Tome 3.

FROM THE RADIOLOGICAL DEPARTMENT OF THE SERAFIMER-LASARETT, STOCKHOLM
CHIEF: PROFESSOR G. FORSSELL

Hemophilia and hemophilic arthropathy

by

T. Klason, M. L., Stockholm

(Tabulæ V, VI, VII)

GRANDIDIER defines hemophilia as a disease, partly congenital partly hereditary, which is distinguished by a general hemorrhagic diathesis with pains and sweelings in the joints and which usually continues during the remainder of the patient's life (1).

The chief characteristic of the disease is the delay in the coagulation of the blood, in the body as well as without. Nor is the coagualation, when it finally occurs, as complete as in normal persons. With true hemophilia, in contrast with a temporary condition of hemophilia, this slowing down of the speed of coagulation of the blood is already existent at time of birth, and is present during the whole life. As far as I have been able to find out, there have been no investigations made to discover whether or not the time of coagulation during the life of a bleeder becomes more normal with growing age. It has, however, been often shown that the hemophilic symptoms become milder or cease as the patient becomes older. This naturally depends to some degree on the fact, that the patient learns to avoid the most important cause of bleeding, namely traumata. Besides the retarding of the blood's coagulation speed, he is also mentioned, especially by older authors — Virschow and others — that the blood vessels are fragile, constricted and easily ruptured by wounds.

There is an extensive literature dealing with the process of coagulation of the blood and the causes of slow coagulation in hemophilic blood. The course of coagulation in normal blood is, according to the generally accepted opinion, the following: The irritation of foreign bodies, or rough vessel walls on the blood corpuscles causes them to throw off thrombokinase. Through the influence of thrombokinase on thrombogen, by the presence of dissociated calcium salts, thrombin is formed. This in turn changes fibrinogen into insoluble fibrin which forms in a net-work.

(2). There is thrombokinase not only in the protoplasm of blood cells, but it seems as if it could be formed in the protoplasm of all tissue cells.

According to SAHLI, MORAWITZ, LOSSEN, etc., the essential thing in hemophilia is the decreasing ability of the protoplasma of the blood cells especially of the *thrombocyts*, to produce thrombokinase in sufficient quantity (3). MORAWITZ states as follows:

»Wir haben es also bei Hæmophilie zu thun mit einer chemischen (fermentativen) ererbten Abartung des Protoplasma der geformten Elemente des Blutes, vielleicht aber auch der Zellen des gesamten Organismus». (4).

GRESSOT takes a somewhat different standpoint (5). According to him hemophilic blood coagulates if defibrinated blood or only common blood-serum is added. Moreover, the addition of organic extract from a bleeder causes the hemophilic blood to coagulate. With this as a foundation, he denies the theory of SAHLI and MORAWITZ about a general lack of thrombokinase and says that in hemophilia the thrombokinase is absent only in the bloodcorpuscles and in the endothelial cells, not in the organic cells. KLINGER (5 a) has an opinion which is different from the two mentioned above. He considers that there is a sufficient quantity of thrombokinase and fibrinogen in hemophilic blood. The retardation of coagulation depends on the lack of prothrombin which latter, when worked on by secretion from an injury in the presence of dissociated calcium salts, forms the thrombin necessary for coagulation.

Hemophilia has been observed in most countries but with very differing frequency (6). The disease is especially common in Germany and also among the Germans who have emigrated to North America. It is also common among the Jews. In medical literature are described two kinds of hemophilia, one congenital and one hereditary form. The latter is often worse and large numbers of the cases have died at birth from profuse hemorrhages.

There are exhaustive investigations of bleeder families and now we are well acquainted with the course of the disease, in those families. LOSSEN explains it as follows: »Die Anlage zu Blutungen wird nur durch die Frauen übertragen, die selbst keine Bluter sind. Nur Männer sind Bluter, vererben aber wenn sie Frauen aus gesunden Familie heiraten, die Bluteranlage nicht» (7). This statement is based on an investigation through four generations of a bleeder family with 207 members and of these 37 were bleeders.

Through later researches it has been shown that LOSSEN's rule holds good for the most part. (8, 9, 10). Here also, inheritance follows MENDEL's law, so that predisposition for hemophilia is dominant for men and subdominant for women. It is also interesting that another anomaly, namely colour-blindness, follows the same law.

In contradiction to LOSSEN's view opinions have changed concerning the possibility of hemophilia occurring in women (11). Grandidier gives the distribution between men and women as the ratio of thirteen to one. There are also descriptions of haemorrhages into the joints in the case of females suffering from hemophilia (12).

From the literature BOUCURA (13) has recently collected 197 cases of hemophilia in women and he says that, through an accurate analysis of these cases, he has come to the conclusion that it is not yet proved that hemophilia occurs in women. At any rate one may be sure that real hemophilia in women is very rare and it seems to me that cases described, especially in gynecologic and obstetric literature, should be accepted with great care. This is especially necessary where the symptoms occur in advanced years. A large number of these cases could certainly be attributed to a hemorrhagic diathesis, and the retarded speed of the coagulation, causing the prolonged bleedings, is only a symptom of another disease.

Hemophilia often appears at birth in the form of prolonged external and internal bleedings (14, 15). Often, however, the first symptoms are observed when the child begins to walk. The most usual signs then are long traumatic bleedings from open wounds and large subcutaneous extravasations and bleedings from the mouth and nostrils. When the teeth are being cut or extracted there are often prolonged bleedings, a violent sneeze also may be enough to cause a fatal epistaxis.

In more serious cases, especially hereditary ones, there may also be spontaneous internal bleeding. It often seems as if some organs in an individual were more susceptible than others.

The more common of the extravasations of blood occur in the joints, (47) and it has long been known that hemophilia patients suffer from pains and swellings in the joints. (OTTO 1803) and TARDIEU (1841) called attention to spontaneous swellings of the joints of bleeders (16). REINERT in 1869 pointed out that the swellings were caused by bleeding into the joint cavity (17). This view gradually won general approbation but it was claimed by many that the permanent changes resulted from a secondary cause, such as rheumatism or gout.

BOWLBY (18) says that in bleeders there is a tendency to bleeding into the joints as a direct result of lesion, but he says further: »There is a special tendency in many bleeders to attacks of acute inflammations which very closely resemble those of the more severe forms of osteoarthritis». He considers also that the joint modifications cannot be explained as being caused only by bleeding. He says: »As to the explanation of the morbid appearances, I think that it may safely be affirmed that the latter cannot possibly be adequately explained by the hypothesis

that all of these lesions are results of blood extravacations and yet this is very commonly stated and taught».

Complete understanding of these arthropathies was first arrived at through KÖNIG's fundamental work (19). The process and the pathological anatomy explained by him have been confirmed by later authors and his division into three stages has been generally accepted. KÖNIG's stages are the following:

1. *First bleeding.*
2. *Panarthritis.*
3. *Final stage.*

This division is based chiefly on the pathologic-anatomical peculiarities of the disease. In the first stage the joint capsule is distended by blood coming from a rupture in the synovial membrane. It is noteworthy that one so seldom finds in literature any description of periarticular bleedings. This may possibly be due to the fact that the synovial membrane is more sensitive to lesions than the periarticular tissue and bleeding takes place chiefly inward in the joint cavity. After from eight to ten days the blood is usually reabsorbed and the joint resumes its normal functions. By degrees the blood and the blood clots, resulting from new bleedings into the joint, exert a chronic irritation on the synovial membrane. This hypertrophies, becomes villose and brown-coloured from the blood pigment. In the capsule is found a blood-coloured serous or seromucous fluid often abundantly supplied with fibrin which is sometimes caked together into smaller or larger particles resembling »lipoma aborescens». The changes are not confined to this, however. The cartilage loses its gloss, it is covered with fibrin and, if this is removed, there may be detected cartilage defects extending even into the bone. Gradually the capsule becomes more and more sclerosed. The surfaces of the bones which have lost their cartilages cannot retain their form and become flat, motility diminishes and there often occurs a condition of subluxation. The final stage consists of a more or less complete obliteration of the joint cavity with a sclerotic connective tissue extending between the cartilage-deprived surfaces of the joints. According to KÖNIG, all the changes may be simply explained by the mechanical and chemical irritation exerted by the blood and the blood clots on the joint capsule and the cartilage (20, 21, 22, 26).

No joint escapes. It is more often the larger joints which are affected and of these the knee joint is especially exposed. In this latter, movement is usually also most affected. This condition is clearly shown in PIOLLET's collection of thirty-two cases (23). In all of these cases the knee joints were affected; in six instances only on one side. The proportions in the different joints was as follows: — the knee joints were

affected 32 times, elbows 16, ankle 12, hips and shoulders 5 times each, fingers 4 and the toes twice. Evidently the preference is for the larger joints; especially the knees and elbows, both of complicated structure and much exposed to injuries. That the knee joint is affected more than all the others, does not seem to me to be accidental. It is exposed to a greater degree than the others to injuries and is of especially complicated structure and difficult to protect in walking.

The clinical symptoms of these arthropathies are very variable and it is just this variation which is characteristic. Often after a very slight trauma a joint swells and the cavity becomes filled with blood from the capsule. The subjective discomfort is small as a rule. In rarer instances there may be severe pains and fever, as well as swelling around the joint as in acute osteomyetitis (20). The blood is usually absorbed within about a week and the joint resumes its normal function. Relapses are very common and, even after 45 such, the joint may function fairly well (24). Gradually, however, the chronic irritation caused by the blood becoms manifest, The capsule now feels swollen and perhaps somewhat sclerosed, the joint cavity is expanded, the ability to move is reduced and often a slight crepitation accompanies the movements. In this stage of panarthritis (KÖNIG), the spontaneous joint bleedings are very characteristic. They may occur even when the patient is asleep. They may be naturally explained as resulting from the crushing and erosion of hypertrophic villi or firmly attached clots. A single movement of the seriously hyperemic synovial membrane, such as in bending or stretching, seems to me to be enough to cause a slight lesion sufficient to cause a severe attack of haemorrhage. With increase in age, the chronic capsule irritation lessens, the joint becomes stiff and there is often a subluxation. The final stage becomes a more or less pronounced condition of ankylosis which is often combined with atrophy of the muscles in the extremity concerned. The disease has now reached its ultimate phase and, with more or less deterioration in the joint cavity, the bleedings into the joint usually cease to occur.

These symptoms may be observed even during the first years of life, but they usually first appear when the child learns to walk. They begin quite usually also at school age when children are more exposed to injury than before.

Opinions differ somewhat concerning the frequency of these arthropathies. LINSER considers that they exist in all cases of hemophilia (25). It appears that this is not true, however. In LOSSEN's above-mentioned investigation of a bleeder family comprising 207 members, there were 37 bleeders and of these 9 or perhaps 11 had joint symptoms. Seven out of the 37 bleeders died within two years after birth, consequently

of 30 who attained greater age, about one third had symptoms of bleeding at the joints.

Some of these athropathies have been studied by means of roentgen rays. The descriptions of the visible changes are often so inconcise and incomplete that they are not of great value. Neither is there any complete collection of observed changes.

As far as I have been able to discover, SHAW was the first who described a case of this kind (27). It concerned a man thirty years old who had had numerous bleedings in the larger joints ever since his childhood. He describes changes as resembling those which accompany a rheumatoid arthritis with constricted cartilages, enlarged bone ends and lips on their edges. In a reproduction of the elbow is seen the reduction of the joint cartilage, considerable flattening of capitulum radii and also lipping on the medial side of the ulna joint surface.

In 1898 came SABRAZÈ'S and CABANNES' research (28). In one case, which clearly belongs to KÖNIG'S second stage, the authors describe normal joint surfaces, but between the patella, the anterior surface of the condyles of the femur and the tibia an opaque zone in which there were two small spots. In a later stage with ankylosis, the joint surfaces were normal. Their investigations are nevertheless incomplete because they did not study the joints in a sufficient number of projections.

Later GOCHT described decalcifiation, uneven epiphyseal lines, diminished joint cartilages, uneven joint surfaces and densified capsule shadow (24). Moreover, in an advanced case there was a decrease in the volume of the epiphysis. CARRIERE, in a rather moderate case, saw a shadow between the joint ends of the knee with normal joint surfaces (30). MURMINGAS mentions that there is a predilection for the knee joint and he describes the diminution of cartilage, uneven joint surfaces and a dense capsule shadow (31). He has three cases, all rather advanced, and the modifications are observed in the knee, hip and elbow joints. In 1911 came MENAUD'S work (32). In a case of average severity with some diminution of motility and some temporary swellings in the history, the following was indicated on elbow and knee joints: the patella and the epiphysis were enlarged and very much deprived of lime; the epiphyseal cartilages broader than usual and irregular. The picture is named, »Ostéite hypertrophiante épiphysaire totale avec décalcification intense». He does not give any explanations about the joint capsule.

MANKIEWICZ first reports a knee-joint case of Emmerrich Gerö where the joint cartilages were constricted, the ends of the epiphyses uneven and there were a number of shadows in the capsular region (33). He himself has two cases, both knee joints. In one was a great deficiency in lime, uneven joint surfaces and small shadows within capsule. In

the other, an advanced case, there were modifications appearing like those of arthritis deformans.

Neuman published a paper during the same year (34). In an earlier case, characterized by some impairment of function in the knee joint, and also muscular atrophy, he saw uneven epiphyseal lines, decalcification, condyles of indistinct outlines with some enlargement of the medial condyle and the patella lying firmly against the planum popliteum. There was also a deepening of the capsular shadow. In a another very advanced case with affection of most of the large joints there was a decrease in the thickness of the cartilages, as well as lips and deformities of the bones in the joints.

Martin du pan in 1915 reports two cases both of which had a history of knee, elbow and hip joint swellings (35). He notes enlargement of the ends of the bones and contracted cartilages. He also states that the trochanter minor is enlarged. This enlargement seems to me to be a possible result of projection. It is, moreover, not so large but that it could lie within physiological limits. He does not believe that roentgen pictures alone could constitute a diagnosis. Rhonheimer describes, in a case of average severity, decalcification, blurred epiphyseal lines and uneven joint surfaces; on the ankle joint there was a destruction of the tibia epiphysis and of the upper part ot the talus (36)

The two following authors give somewhat more detailed explanations. Engels mentions a somewhat advanced case with muscular atrophy and restriction of mobility in the most of the large joints (37). In the knee joints he describes the ends of the bones as being flattened and as having edges. The cartilages were constricted, the eminenta cruciata was crater-shaped, the fossa intercondyloidea was enlarged, the joint surfaces were uneven and the capsule shadow was dense. In addition, he describes some sharply bordered spots where the bone structure was thinned. These spots ranged in size up to that of a pea and were located near the joints. He explains that these spots are caused by subperiosteal bleedings which lead to absorption of the bone. He also points out as characteristic flakiness and scaliness of the capsules caused by »ossification».

Escande and Tapie have quite recently related a case (38). A nine-year-old boy had had a large number of swellings in the knee joints, leading to subluxation, muscular atrophy and also thickening of the capsule. Under roentgen examination of the knee joints there appeared to be an intensive decalcification of the epiphysis, a slight unevenness of the joint surfaces without lipping, a diminishing of height in the cartilages and also an enlargement of the patella. Between the patella, the tibia condyle and the anterior surface of the femur there were uneven shadows

with hazy outlines. The case is incompletely investigated, in that only side pictures were taken. WILSON has published a description of two bleeder brothers (39). Ono was nine and the other twenty-four years old. The younger brother had had a large number of bleedings in nearly all of the joints, these being caused either by trauma or occurring spontaneously and leading to some decrease in the functioning ability. Moreover, he had had attacks of epistaxis, bleeding from the gums and cerebral hemorrhage. The hemorrhages into the joints had been accompanied by some pain, limitation of movement and fever. As a rule, these symptoms disappeared of their own accord within ten days. A roentgen picture of one elbow joint showed no changes. The other side showed an unusually early development. On a plate taken of the knee joint it was seen that the cartilage was of normal thickness; along the outlines of the condyles of the femur there appeared crowded streaks and the outlines of the epiphysis were hazy. The last three years the elder brother had had several joint swellings with accessory restriction of motility. From a roentgen picture of an elbow WILSON describes the lipping on processus coronoideus and on condylus internus. Judging from the reproduction, it seems that capitulum radii is somewhat flattened. Dealing with the knee joints, he describes a hypertrophic arthritis deformans. The reproduction shows besides, constricted cartilage, flattened joint surfaces, enlargement of fossa intercondyloidea and increased density of the latter. Possibly there is also an increased lack of lime in the bones.

Quite recently, October 1920, there appeared a case described by YOVTCHITCH in the Revue Médicale Francaise. It concerns a knee joint of an eight-year-old child. According to a short abstract in the Journal de Radiologie, etc., 1921, the combination of the roentgen picture with the clinical history makes it possible to secure a correct diagnosis. The abstract did not give any details (40).

As seen from this report, much uncertainty still prevails and, apart from the loss of lime, no prevalent character seems to be determinable. In many instances the discoveries contradict one another. Thus, in one case of ankylosis there may be no changes in the bones while in the other deformations may exist early. It seems to me that this incongruity is the result partly of incomplete investigation of the cases, and partly of the failure to take into account the stage of disease in which the patient may be.

I have had opportunity at the *Serafimer Lasarett* of examining two hemophilic cases, both males. One was an eleven-year-old boy and the other a nineteen-year-old youth from a family of bleeders. For the third case I am much indebted to Professor G. FORSSELL who, from

his private institution, turned the case over to me for publication. It concerns a man of thirty of a family of bleeders.

Case 1. (Tab. V. Figs. 1—4, Tab. VI, fig. 1). K. G. P., eleven years old, illegitimate birth and only incomplete history could be obtained. As far back as the patient can remember, he developed large and rather painful blue marks after light blows. At six years of age he had an injury to the knee which swelled very much. Since that he has several times had swellings at the joints, not only after injury but also spontaneously while sleeping. The knee, elbow and hip joints were affected and especially the right knee joint. These swellings were accompanied by some pain and loss of mobility and they passed away of themselves within about a week. For some time he has been under observation for tuberculosis genu dextri. He has been taken to the EUGENIA HOME. There he at one time had blood in the urine and also elbow and knee joint swellings several times during sleep. I had the oppurtunity of examining the patient on the morning after such a night and then one elbow was swollen. The joint capsule was distended, there was some tenderness on pressure over it and there was also reduction of motility. All these joint symptoms passed away after a week.

Condition on admission: rather small for his age, thin, pallid skin with translucent superficial veins; poor muscular development. Shoulder, hand, foot and hip joints normal on clinical examination.

Knee joints: Right knee joint: — motility lessened; can be bent from 25 to 90 degrees; capsule not distended but feels sclerosed; no local tenderness on pressure. Condyles of the femur feel somewhat large and the joint on this side measures 1.5 cm. more in circumference then on the left. Left knee joint: normal motility; on palpation nothing seemed abnormal except some possible sclerosis of the capsule.

Elbow joints: on both sides the capsule feels somewhat thickened, especially over the capitulum radii, and the motility is slightly lessened on the left side, but beyond this, palpation gives nothing pathological.

The patient has been examined here and plates are taken of the knee, elbow and hip joints, as well as of the hand, shoulder and ankle joints. Apart from a slight loss of lime in the right ankle joint, the roentgen pictures showed the three latter to be normal. On the plates of the left hip joint no change can be seen. On the right hip joint there appears possibly the same thinning in the bony structure which ENGELS noted (Tab. VI, fig. 1) so that there is in collum a bean-sized thinning in the bone structure with a slightly thickened border zone. Apart from these, there are no changes to be seen on this side.

The right knee joint (Tab. V, Figs. 3, 4) clearly shows changes. Femur and tibia diaphysis are thin but the femur and tibia condyles and also the patella are larger than on the other side. They are decalcificated and have hazy bone structure. The capsule shadow is dense and cloudy. The cartilages of the joint are diminished in thickness and the bone surfaces of the joint are a little uneven but with a general preservation of the outline. The frontal picture shows some enlargement of fossa intercondyloidea toward the medial side and its outlines are a little hazy. The epiphyseal lines are slightly more hazy than on the other side.

Left knee: No alterations except a cloudy density in the back parts of the capsule.

Elbow joints: (Tab. V, Figs. 1, 2) the bones are strikingly slender, with increased breadth of the humeral epiphysis. The size and number of the epiphyseal centres are normal for the patient's age but the growing together of marrow in the trochlea and capitulum humeri shows a somewhat premature development. On the

plates there further appears a slight decalcification and the joint cartilages are reduced in thickness but the bony surfaces of the joint are regular. Facies semilunaris ulnae is flatter than normally and enlarged. The marrow in the capitulum radii is pressed flat and the collum radii is broader than usual. The capsule shadow shows a slight but distinct modification. It is more prominent than normally and within it appears a cloudy density on the anterior surface and at recessus sacciformis. There is also an interesting enlargement of flossa coronoidea and olecrani and on the left side no bone structure can be seen there. This modification may go with the enlargement of the joint surface on ulna.

Case 2. (Tab. V. Figs. 2—4). Man, nineteen years old. The parents not bleeders but the patient has an uncle who is a bleeder and who suffers from the same joint disease as the patient himself. When he was about ten years old he was twice treated for keratitis parenchymatosa in a hospital. Since the last visit to the hospital he has never had any trouble from his eyes and now his eyesight is about normal. As a child he had some swelling of the joints which was the result of injury. Later there were spontaneous, as well as traumatic swellings in the elbows and knees; mostly the latter. His joint symptoms have not been accompanied by much discomfort but the knee joints have become rather stiff. Besides this he has had a number of other hemophilic symptoms such as subcutaneous bleedings after slight traumata, lengthy bleedings after tooth extraction, bleeding from the gums when brushing the teeth and nosebleed after sneezing. Just before he came to the Serafimer Lassaret his left knee joint had swollen a couple of times without evident cause and there had, moreover, been pain in the left lumbar region and blood in the urine. His came to the medical department, clinic 2 (Professor JACOBÆUS), on September 17, 1919. When he arrived he had blood in the urine but the urine became clear after 14 days in bed and it has remained so during his whole stay.

Condition on admission: a feebly developed youth with thin hair growth around the genitalia and in the axillæ; skin pale; slight anæmia with 3,500,000 red blood corpuscles and 9,300 white ones: hemoglobin 62 %, by SAHLI's method; coagulating speed of the blood 55 minutes (control test of normal 7 min.). On clinical examination nothing was noticed in the spine, shoulder, hip joints, hand and foot joints.

Elbow joints: In both the capsule was thickened and the mobility somewhat diminished.

Right knee joint: stretching normal; bending up to about 90 degrees; capsule a little sclerosed and protuberances can be felt along the joint edges.

Left knee joint: stretching normal; bending up to 90 degrees; marked crepitation with movement; capsule distinctly sclerosed; on medial side of the joint there can be felt protruding edges along the joint crevice. These edges are of the consistency of cartilage.

No free fluid is evident anywhere, nor is there any tenderness on pressure in either elbow or knee joints.

The patient was examined at the Roentgen Institute. On the plates of the knee and elbow joints the following condition was noted.

Left knee joint: (Tab. VI, Fig. 2) the capsule shows an increased density with *cloudiness;* the joint cartilages are reduced in size and the bone surfaces of the joint exhibit a wavy unevenness which is most pronounced on the medial femur condyle. On the lateral one there is a slight turning out of its lateral edge. Fossa intercondyloidea is enlarged and its limits are hazy. The eminentia intercondyloidea is also deformed and supplied with some irregular processes and there is also some decalicification of the bones.

Right knee joint: (Tab. VI, Fig. 3, 4) shows on the whole the same modifications as the left one. There is the same cloudiness of the capsule, most pronounced in the fossa intercondyloidea where a definite soft shadow can be distinguished from the surrounding tissues and is also present at the medial part of the capsule where there also are a few small denser spots. The cartilages are thinned and the lateral meniscus is condensed. It appears plainly on the frontal picture and has uneven surfaces, which is also the case with the joint cartilages here. The joint surfaces have the same roughness as on the left side but there is no alteration of the fossa and the eminentia intercondyloidea. The epiphyseal cartilages show no modifications on either side and parallel with them in the tibia and femur there are seen condensed streaks of lime.

The plates taken of the *elbows* show very unimportant changes. On the left side there is a little unevenness of the ulna joint surface and also a flattening of capitulum radii. On the back side of ulna there is a dense periostitis. On the right side there shows a little unevenness in the medial part of the ulna joint surface and also a periostitis on the same place as on the left. No decalcification, no reduction of the cartilages, no condensation of the capsule can be detected on either side.

Case 3. (Tab. VII, Figs. 1—4). A thirty-year-old man; an uncle died of hemophilia; two male cousins on the mother's side bled to death as children. During his whole life the patient has occasionally had swellings and pains in the joints. The elbow, hand, wrist and knee joints have been affected; especially the knee joints. These swellings were often the result of injury but lately they also occurred without evident cause. During the last ten years the acute swellings have become rather rare but the knee joints have stiffened. Besides these troubles in his joints, he had a spontaneous, severe and lengthy intestinal bleeding when he was eighteen years old.

Condition on admission: pallid complexion with thin skin and translucent superficial veins; poor muscular development, especially in the thighs and calves. Ankle, hip, shoulder and hand joints clinically and roentographically normal.

Elbow joints: motility normal except for a slight limitation on extension on both sides; the capsule feels a little sclerosed but not distended; no local tenderness.

Knee joints: Extension somewhat limited; flexion possible up to 50 degrees; slight crepitation on moving; joint capsule feels sclerosed but not distended; no tenderness on pressure over the joint.

On the plates taken of the *knee joints* (Tab. VII, Figs. 1—4) important alterations are seen, very much resembling an arthritis deformans. The changes are two-sided and the two sides do not diffes to any great extent. The lime content is somewhat lowered in the metaphysis. In the vicinity of the joint surfaces, however, there is a bony sclerosis with dense bone structure. The joint capsule is denser than it normally is. The cartilages are everywhere reduced in height. The bone surfaces show a wavy unevenness and their edges in many places are thrust out like ridges. The fossa intercondyloidea is enlarged; it has irregular outlines and it seems dense. Eminentia intercondyloidea is likewise enlarged, with the indication of a crater form on the left side. There is no definite enlargement which can be shown on the ends of the joint bones but the femur condyles on the left side seem to be somewhat bulky.

The modifications resemble in a certain degree the *hypertrophic form of an arthritis deformans* but it differs distinctly from this; above all in the wavy unevenness of the joint surfaces. Moreover, it seems to me that the capsule condensation, is less usual in arthritis deformans (44, 45). On the plates of the *elbow joints* no modifications show, except a slight increase in the density of the capsule shadow.

These three cases represent all the different stages, from the fairly early stage to the advanced stage, and they make possible a study of the development of the alterations, as detected by the roentgen rays. At the very earliest, one naturally sees on the plate only a distention of the joint capsule and when the blood is reabsorbed the joint gives a normal picture. The roentgen examination becomes of value with the development of the existing modifications in the cartilages and the joint capsule.

A common feature of all cases is the deprivation of lime in the joints most affected. The epiphyseal cartilage exhibits no definite changes. In the *first case* there is, on the joint least affected — that of the *left* knee — only a slight increase of thickening in the capsule and this is chiefly in its posterior part. There is nothing more! On the elbow joints there are capsule and cartilage modifications and also changes in the bone. The *capsule* changes appear as *increased wavy thickening*. This seems to me to be very characteristic of hemophilia. It has been noted before but it appears that generally it has not been credited with much importance. I consider that it is caused by the organization of the shrinking of *blood clots*. The reason for the distinct appearance of this local thickening is undoubtedy that there is no periarticular oedema covering the details in the thickness of the capsule.

The cartilage modifications consist of a diminution of the thickness of the cartilage. The bone changes comprise a slight flattening of the joint surfaces. This is surely accessory to cartilage diminution and is seen in the smaller joints comparatively early.

In the knee joints with their larger surfaces the deformity does not seem to come on so early. In the *elbow* joints there is a premature bone development and on the *right* knee joint there is a local growth of the ends of the bones. There are, moreover, known cases which are analogous and where a chronic irritation causes the ends of the bones to become locally hypertrophied and the condition does not seem to me to be especially pathognomonic of hemophilia.

The capsule and cartilage changes on the *right* knee joint, which is most affected, resemble those on the elbow joints. The surfaces are uneven, certainly depending on local cartilage destruction, but with retained outlines. In addition there is local enlargement in fossa intercondyloidea. This joint is also that most affected in the history.

In the *second* case the modifications are more advanced. The partly diffuse, partly local increase in density of the capsule shows clearer now. A well-outlined *shadow* on one side in *fossa intercondyloidea is interesting*. It is certainly a *shrunken clot*. In some places the increased density of the capsule has nearly reached the density of lime. The cartilage is reduced in thickness and one can see directly the unevennesses in it.

There appears also the lessening in thickness and uneven surfaces of a meniscus. The bone modifications are more advanced too. There is a wavy unevenness in the outlines of the joints surfaces. Fossa and eminentia intercondyloidea are *enlarged* and have hazy outlines. This latter impresses me as being an especially distinct feature of hemophilia. The enlargement on the medial side of the fossa is striking. I consider that this depends on bleedings at the attachment of ligamentum cruciatum posterius which is attached here. This ligament tightens when the knee joint is stretched and this strain seems to me to be enough to cause bleeding. It is known that bleedings can cause bone deterioration. Ihus STARKER (46) has noted a subperiosteal hematoma in hemophilia which damaged the greater part of the femur. Besides the above mentioned, there are edges of the joint surfaces.

The *third* case shows the most advanced changes. Here the capsule has only a diffuse increase in density, without the above indicated cloudiness. This certainly is due to the fact that he has not had any acute joint swellings during the last three years and it bears witness to the fact that this cloudiness is due to blood clots. The cartilage is atrophied and the joint surfaces exhibit a slight unevennes. The *fossa intercondyloidea* is enlarged.

There are further changes such as occur in an arthritis deformans of hypertrophic character with lipping at the bony surfaces and increased lime content in these. Some authors have pointed out important deformities and lipping in advanced cases. It is quite possible that individual variations in the power of resistance of the cartilage and the bony substance play a part here. It is also probable that an early onset of the disease leads to greater deformities.

Hemophilia panarthritis very much resembles clinically tuberculosis in the joint (48). A careful history of the disease often gives an explanation. Tuberculosis is of progressive character and, if it infects the larger joints, it does not usually affect more than one or two. Hemophilia begins with acute joint swellings, but later the remissions are characteristic. It does not affect the general condition of the victim and it does not cause any lasting fever or fistula formation. Function is good in spite of *recurring attacks* of swelling. It usually affects several of the larger joints. Roentgen pictures afford valuable assistance here. One never finds bone destruction in the same way as in tuberculosis and the decalcification is never so intense. Atrophy of cartilage and increased density of the capsule occur in both diseases but the cloudiness of the capsule, which is so characteristic of hemophilia, seldom exist in tuberculosis. If there is calcification in tuberculosis of the joints it has a typical

granular appearance and in this it differs from hemophilia with which there are hardly ever lime deposits in the capsule.

During childhood an arthritis deformans occurs which might be considered as furnishing a source of confusion with hemophilia (42, 43). This arthritis begins insidiously with feber and doughy oedema of one or several joints.

After a long spell of fever, a shrinking and loss of function occurs, combined with marked atrophy of the muscles. In the roentgen picture one seldom sees cartilaginous or bony changes in this disease. The process seems to be mostly confined to the capsule. The course of the disease and also the absence of bone and cartilage modifications distinguishes it from hemophilia. An arthritis deformans, and a fully developed hemophilic arthropathy in its final stage, seems to me, on the contrary, to shew alterations on a roentgen examination which can scarcely be differentiated from each other. It is, in the meanwhile, less important because the clinical course of the two diseases permits a certain differential diagnosis (44, 45).

With the tabetic and neurotical arthropathies there are usually condensations of soft parts in the vicinity of the joint which resemble, to some degree, these occurring in hemophilia (41). These neuropathric arthropathies are distinguished from hemophilia, with its long spells and its comparatively slight bony destructions, by severe deformities, accompanied by good retention of motility.

Thus it seems to me that with hemophilic arthropathies there are characteristic modifications, beginning with capsule and cartilage alterations and later the occurence of decalcification and deformations of the bones. It seems to me that the cloudiness in the capsule is especially characteristic and in later stages a wavy unevenness of the joint surfaces, and when the knee joints are infected, the enlargement of eminentia and fossa intercondyloidea; especially on the medial side. In still later stages the alterations become less characteristic and they resemble those of a hypertrophic arthritis deformans. A roentgen examination with careful reference to the history and the clinical signs seems, therefore, to have a decided value in the diagnosis. And in consequence also in the treatment (49).

Summary

References in literature. The writer has himself three cases of hemophilic arthropathies showing different stages. As characteristic of their X-ray picture he states: in the early stages a cloudiness of the capsule

from blood clots and later decalcification, alteration of the cartilages and deformations finishing with the picture of a hyperthropic arthritis deformans.

The knees are the most affected of all the joints and besides the abovementioned alterations in the capsule and cartilages there are deformations and enlargements of eminentia and fossa intercondyloidea as the results of hemorrhages in the attachments of ligamenta cruciata.

Literature

1) Grandidier. Cit. by Neuman. l. c.
2) H. Rosin. In Kraus and Brugsch. Berlin 1920.
3) Kottman and Lindsky. Münch. med. Wochenschrift 1910.
4) P. Morawitz and J. Lossen. Deut. Archiv f. klin. Med. 1908.
5) Gressot. Zeitschr. f. klin. Med. Bd LXXVI.
5 a) R. Klinger. Zeitschr. f. klin. Med. Bd LXXXV 1918.
6) M. Matsuoka. Deut. Zeitschr. f. Chir. 1909.
7) J. Lossen. Deut. Zeitschr. f. Chir. 1905.
8) G. Riebold. Med. Klin. 1913.
9) Vogt. M. m. W. 1919.
10) Ö. Mehn-Andersen. Med. rev. Bergen 1918.
11) O. Hanssen. Norsk Magasin f. Lægevidenskab 1912.
12) Brodnitz. M. m. W. 1905.
13) C. Bocura. Leipzig 1920.
14) N. v. Etlinger. Jahrb. d. Kinderheilk. 1901.
15) A. Chaning Pearce. Brit. med. Journ. 1898.
16) Otto and Tardieu. Cit. by Menaud. l. c.
17) Reinert. Cit. by König l. c.
18) Bowlby. St. Bartol. Hosp. Rep. 1890. Vol. XXVI.
19) F. König. Saml. klin. Vorträge (Volkman) 1892 nr 36.
20) F. Froelig. Zeitschr. f. ortop. Chir. 1905.
21) v Stubenrauch. M. m. W. 1910.
22) Tillman. Cit. by Neuman l. c.
23) Piollet. Gaz. d. Hop. 1902.
24) H. Gocht. Arch. f. klin. Chir. 1899.
25) P. Linser. Beitr. z. klin. Chir. 1896.
26) H. Schloessmann. Beitr. z. klin. Chir. 1912.
27) J. E. Shaw. The Brist. med.-chir. Jour. 1897.
28) Sabrazès and Cabannes. Cit. by Menaud l. c.
30) Carrière. Cit. by Menaud l. c.
31) Murmingas. Archiv f. klin. Chir. 1902.
32) L. G. E. Menaud. Thèse de Bordeaux 1911.
33) Mankiewicz. B. k. W. 1913.
34) D. Neuman. Diss. Berlin 1913.
35) C. Martin du Pan. Rev. med. de la Suisse rom. 1915.
36) E. Rhonheimer. M. m. W. 1917.

Fig. 1. Case 1. Right elbow.

Fig. 2. Case 1. Right elbow.

Fig. 3. Case 1. Right knee.

Fig. 4. Case 1. Right knee.

Fig. 1. Case 1. Right hip.

Fig. 2. Case 2. Left knee.

Fig. 3. Case 2. Right knee.

Fig. 4. Case 2. Right knee.

Fig. 1. Case 3. Left knee.

Fig. 2. Case 3. Left knee.

Fig. 3. Case 3. Right knee.

Fig. 4. Case 3. Right knee.

37) H. ENGELS. Fortsch. Bd XXV.
38) F. ESCANDE and J. TAPIE. Journ. de Radiol. Paris Tome III.
39) MAY G. WILSON. Am. Journ. of Dis. of Child. 1919.
40) YOVTCHITCH. Ref. in Journ. de Radiol. Paris Tome V.
41) MEYER-HÜRLIMAN. Korr. Blatt f. schw. Ärtzte 1918.
42) JOS. WESTERMEYER. Jahrb. f. Kinderheilk. 1915.
43) E. RHONHEIMER. Jahrb. f. Kinderheilk. 1917.
44) E. JACOBSOHN. Mitteil. a. d. Grenzg. d. Med. u. Chir. Bd XX.
45) E. JACOBSOHN. Ibid. Bd XXV.
46) L. STARKER. Mitteil. a. d. Grenzg. d. Med. u. Chir. Bd XXXI.
47) A. McLANE HAMILTON. Med. Rek. 1891.
48) VULLIET. Rev. med. de la Suisse rom. 1902.
49) K. P. DAHLGREN. Bruns Beiträge LXI.

FROM THE ROENTGEN DEPARTMENT OF THE ARMY HOSPITAL, STOCKHOLM
CHIEF: N. HANSSON, M. L.

A Case of Fracture of the Cranium with Accumulation of Air in the Cranial Cavity

by

N. Hansson

(Tabula VIII)

In the early literature on this subject there is described a group of 30 cases of so-called *pneumatocele Cranii* collected by Mac. Arthur in the Annals of Surgery and Gynecology of 1905. These constitute all the cases published on the subject up to that time. As a curiosity, it may be mentioned that the one who discovered this disease, and differentiated it from the usual subcutaneous emphysema in the head, was the great Swedish surgeon, OLOF AV ACRELL, who, in his publication »Kirurgiska händelser», communicated the first case of the disease in question. The name pneumatocele was first given by the French physician, CHEVANCE DE VASSY, 1855. None of the cases in MAC ARTHUR's publication have been Röntgen-diagnosed. Most of them refer to the region above processus mastoideus, and are therefore called pneumatocele-supra-mastoidea, and only very few to the frontal region. The accumulation of air has had an epidural location. Very few of these cases are of traumatic origin. But there are a few such described as traumatic cysts after fracture of the cranium with laceration of the brain. The majority of them have originated in patients with morbid changes in the bone in proc. mast., for instance, cellulae or antrum, and the real, so to say, acute causal moment for their appearance is said to have been a sudden increase of the pressure in the nasopharyngeal cavity, such as a violent sneezing, or similar symptoms. The cases have been verified either through operation, or through post-mortem examination.

In the literature of the last few years there appears a case of this kind of pneumatocele cranii supra-mast. — not examined with the X-rays — published by Dr. T. PHEMISTER. It was one of the more rare cases with traumatic etiology and refers to a 12-year-old boy who, after a

knock against proc. mast., gradually developed headache and epileptic fits. Operation revealed an air- and fluid-filled cyst, which had arisen in a seat of contusion in the temporal lobe corresponding to the place for a fracture in proc. mast.

In 1913 M. LUCKET[1] describes in the Annals of Surgery and Gynecol. the first case of air in the ventricles of the brain which has been roentgen-diagnosed before operation. This refers to a 87-year-old man who had been run over in the street and got a fracture on the coronal bone, which went through sinus frontalis dx. and the right orbital roof. The first roentgen photo, which was taken some few days after the injury, certainly exhibited the fracture but no air within the cranial cavity. About 8 days after the trauma, when the pat. had considerably improved, he got a violent attack of sneezing, and instantaneously he felt a violent stinging pain in his head. At the same time, according to his statement, a large quantity (a coffee-cupful) of clear fluid is said to have run out through his nose. The patient afterwards became worse, and showed signs of increased intracranial pressure and meningitis. New roentgen plates were taken and exhibited air in the ventricles of the brain. The patient was operated upon, the right lateral ventricle was then punctured and an air-bubbling fluid came out. Death 4 days after operation from meningitis. On post-mortem examination a fracture was found through sinus frontalis on the right side, which extended further backwards through the orbital roof. The dura adhered to place of fracture and here showed a gap. The soft membranes were likewise adherent at the same place, and on detaching them a laceration in the brain substance was discovered, which showed a connection with the front corner in the lateral ventricle on the right side.

In M. LUCKET's opinion the act of sneezing has pressed the air through the fracture and the injured dura, and further through the laceration in the brain up into the ventricle system. This brought about an acutely severe increase of intracranial pressure, and as an autodecompression from this the cerebrospinal fluid was emptied through the nose.

A. SKINNER[2] reports a similar case of fracture through sinus frontalis and air within the cranial cavity. With the aid of a roentgen examination it was ascertained that there was air before the operation which verified the finding and showed that the air lay subdurally. An analysis was made of the contents and showed 1.8 % oxygen and 98.2 % nitrogen, thus, practically speaking, ordinary air, out of which the oxygen had, for the most part, been resorbed. The patient died of meningitis 20 days after the operation.

T. HOLMES gives an account[3] of a case of fracture through sinus frontalis with air within the cranial cavity — also in this case subdurally situated — death, after operation, from meningitis. And further two similar cases are reported, the one by H. POTTER[4] and the other by J. MAY.[5]

Some time ago I had the opportunity to observe a case of fracture of the cranium with accumulation of air in the cranial cavity.

---

[1] Chicago surgical clinics 1919.
[2] Journ. of Am. Med. Ass. 1914.
[3] Journ. of Am. Med. Ass. 1914.
[4] Am. Journ. of Röntgenology 1918.
[5] " " " " "

The patient was a 36-year-old cavalry officer who, at the beginning of last June, was brought to the military hospital in Stockholm. According to statement, he is said to have always been healthy previously, with the exception of a shorter period of influenza in August, 1918. On the 15th April, 1919, he took part in competitive horse-riding, and during same rode at a great pace right against a corner-post. The patient got a blow on the forehead and was thrown from his horse several yards and fell head over heels to the ground. He at once lost consciousness and for the next two hours remained unconscious. According to information from Dr O. Gertzén at Skövde, who first took care of the patient, he had, in addition to several scratches on his face and .contusions on his body, a gaping bruise over the right eye, showing the bare bone. The wound was sutured and was healed per primam. The pulse was normal and no sign of intracranial pressure was to be found. No hemorrhage from pharynx and ears. The first three or four days the patient had slight fever, wich was thought to be a resorption fever, and afterwards completely disappeared. He had no vomiting but intensive headache. After violent sneezing some hours after the injury he got a hemorrhage in the upper palpebrae and a ptosis of the right upper eyelid. He was nursed at home from the $^{15}/_{4}$—$^{3}/_{5}$ From the $^{8}/_{5}$ in service again. During this time he was troubled partly with headache and tenderness in the muscles of the neck and shoulders, and partly with vertigo which he had felt the whole time when raising himself up from a recumbent or downward-bent position, likewise difficulty in keeping his balance.

In the middle of May, thus about a month after the trauma, the patient in raising himself up in bed one morning noticed a splashing in his head. He could easily produce this splashing when he made slight, quick movements of the head. He himself located the sensation to the nape of his neck. The vertigo and headache still continued, although both had diminished somewhat in intensity. At the beginning of June the patient visited Dr O. Aleman on account of this sensation of splashing. He was received for further examination at the medical department of the military hospital on the $^{5}/_{6}$.

From the status (Head physician, Docent F. Lindstedt) the following was recorded: The patient's subjective trouble consists of the abovementioned sensation of splashing and a slight vertigo. A right-angled cicatrice exists over the right eye, well-healed and without a trace of irritation. On percussion of cranium no soreness anywhere. On auscultation over the cranium, when pat. makes slight, quick movements, the splashing is distinctly heard and sometimes appears more distinct in the nape of the neck, sometimes in the region of the temples. A slight ptosis of the right eyelid was found. Keenness of sight normal on both eyes. The reaction of the pupils to light as well as to accomodation without remark. Nothing pathological in the eye-grounds. On glancing to the extreme right the pat. states double pictures from right eye. The hearing, which has formerly been normal, is now distinctly reduced on the left ear, also on the right, although in a lesser degree. Smell and taste without remark. Facialis everywhere without remark. No deviation of or tremor in the tongue. Sense of temperature, pain and touch everywhere normal. No decline anywhere in the muscular strength. All reflexes normal. Babinski negative. Gait without remark. Romberg negative. Internal organs show no changes. The white corpuscles were counted and showed an amount of 8,500 per cubic mm. Lumbar punction was made, and the pressure was 140 mm. The fluid was quite clear and had about one cell per range of sight.

Roentgen examination on the 7th of June, 1919

On r-grams (Tab. VIII Fig. 1—4) in upright position there is to be noticed on the lateral photo (Fig. 1) the contour of a *semicircular, gas-filled cavity situated within the upper part of the frontal lobe of the brain,* and on r:grams in saggittal direction with the forehead against the plate (Fig. 2) a similar, curved outline encircling gaseous cavity situated on the right side close to the median line. The gaseous cavity is *downwards* limited by a *straight, horizontal* outline, which is formed by a substance of the same density as the surrounding cerebral substance.

This cavity reaches downwards to the base of the skull and from hence about 6 cm. upwards. Forwards it reaches close to the lamina interna ossis frontalis and from hence 5 cm. backwards. Its breadth in the frontal position is 4 cm.

Now some *lateral photos* were taken in a prone position (Fig. 3) with the front against the plate as well as in supine position with the neck against the plate (Fig. 4). In these photos it turned out that the gaseous contents showed off against a surface with a smooth curved outline in the posterior as well as in the frontal part of the cavity. Downwards the gaseous cavity is limited by a plane surface keeping horisontal in all positions of the body, which is evidently caused by *a fluid* that filled up about $^{2}/_{3}$ of the cavity. *The cavity,* which had a diameter of about 5 cm., *was thus well defined and kept its site within the brain in the different positions of the body.*

No gas was to be noticed in the space of the lateral ventricles.

On all the photos *a fracture through the coronal bone passing through the right frontal sinus* was distinguished and a bone fragment of the size of $^{1}/_{2} \times 1\,^{1}/_{2}$ cm. is fractured off the frontal wall and dislocated backwards into the right frontal sinus. The latter is also highly condensed and dimly outlined.

Thus there is evidently *a rounded, well limited cavity in the area of the right frontal lobe of the brain, containing gaseous and fluid contents.*

The patient left the hospital after a few days. On the 20th of July, about 3 months after the injury, the patient notified that the splashing sensation had completely disappeared some days ago. This had happened gradually without the patient being able to give the fixed time for the disappearance. A renewed roentgen examination was then made, and *no trace of air could now be observed within the cranial cavity.*

At the same time the patient was subjected to a renewed examination at the military hospital. With the exception of a slight vertigo, when he raises himself up from a recumbent or downward-bent position, no subjective or objective symptoms whatever were to be found. The patient is still in active service and feels quite well.

No surgical treatment nor post-mortem examination having been performed, it is not possible in the present case to decide with surety the anatomical character of the cavity in the frontal lobe of the brain. I venture, indeed, to designate this injury as a traumatic cyst, well-known from injuries of the brain as well as of the spine. Their origin is explained by the fact that the trauma causes a hemorrhage in the membranes. The blood acts as a foreign body and consequently irritates the soft membranes. This causes a slight schlerosis of same and the adhesive formations, rendering the normal renewal of the cerebro-spinal fluid more difficult. As a further consequence of this hemorrhage the secretion of the cerebro-spinal fluid on the wounded place is increased and, on account of the deficient absorption, the surplus cerebro-spinal fluid cannot be removed, and a retention-cyst is formed here.

As all signs of infection are lacking, it seems very improbable that the gaseous contents of the cavity should have been caused by gas-producing bacterias. As in the other similar cases, where a chemical analysis has been made, I suppose that also in this case *air* has been pressed into the cavity via the fracture crossing the frontal sinus, possibly on the occasion of the sneezing, as in the case of Lucket.

The sensation of splashing may have made itself felt when fluid became present in the air-filled cavity. When the air was completely resorbed, the sensation disappeared.

The case here described is also of interest because, excepting the case published by Potter, it is the only one which has resulted in recovery.

These two patients have not been subjected to operative treatment, whilst all the others have been operated upon and have died. The question now arises how to proceed with these injuries in therapeutic respect. Holmes opines that the correct treatment is a prompt surgical intervention and, as the majority of other writers, he holds that the air draws bacteria along with it, which cause the purulent meningitis that is the cause of death in nearly every case. If this explanation should be correct, it appears very strange that just these two cases, which have not been subjected to operative treatment, are the only ones which have recovered.

Fig. 1. Side-view: Upright pos.

Fig. 2. Frontal view: Upright pos.

Fig. 3. Side-view: prone pos. Forehead against the plate.

Fig. 4. Side-view: supine pos. Neck against the plate.

Summary

The author gives an account of the cases of so-called »*pneumatocele cranii*» in the early and modern literature and describes a traumatic *cyst in the right frontal lobe of the brain,* observed and radiographically examined by him, and containing air and liquid, occurring in consequence of a fracture through the coronal bone, penetrating the frontal sinus.

The patient recovered without surgical treatment.

FROM THE ROENTGEN DEPARTMENT OF THE SERAFIMER LASARETT, STOCKHOLM
CHIEF: PROFESSOR GÖSTA FORSSELL, M. D.

A Plateholder for Precise Roentgenography in Connection with Fluoroscopy

by

Gösta Forssell

At the X-ray examination of the gastro-intestinal tract, and especially at the examination of the duodenum, it is often important to fix on the plate a picture which appears at a certain moment on the screen. For this purpose some fluoroscopic supports are so arranged that the screen

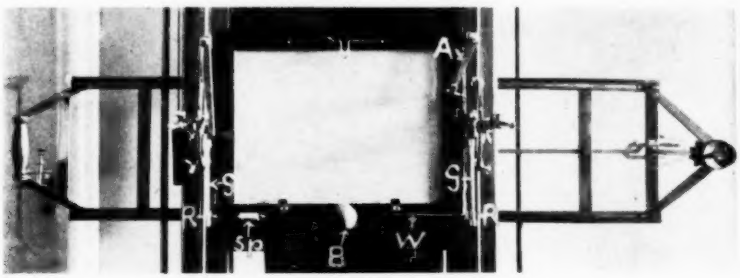


Fig. 1.

is placed in an iron frame, from which it may be removed in order to be exchanged for a photographic plate. I myself have also made such an arrangement on my apparatus for vertical fluoroscopy. (Fig. 1.)

I formerly used plates of the size of the screen when making photographs in connection with fluoroscopy, whereby the cassette was fixed by the same spring-arm (A) as the screen. However, with this arrangement it was neither possible to make an accurate adjustment of a small plate to the sharply limited small area of the screen nor to keep it fixed there.

Since 1917 I have overcome these difficulties by a simple construction, which I demonstrated at the meeting of the »Nordisk Förening för

Medicinsk Radiologi» in Christiania in July, 1919, and at a lecture at the Mayo Clinic, Rochester, Minn. in July, 1920.

On both the left and the right side of the iron frame which surrounds the screen fine vertical guides (G) are placed (Fig. 1.) which reach half way up the height of the screen, and attached to each of these guides is a sliding ring (R) which can be moved up and down the guide. These two rings are connected with each other by means of a thin, horizontal steel wire (W), which is kept tense by a spring. (Sp.). On this wire a wooden ball (B) is suspended which is movable laterally. This ball serves to indicate the centre of a limited picture on the screen

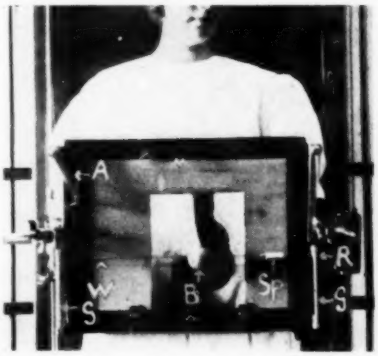


Fig. 2.

Fig. 3.

as well as to fix a cassette exactly to this place. When the indicator-fixator is not used, the ball is lowered to the lower border of the screen (Fig. 1) in order to prevent the ball from being seen on the fluorescent surface.

When observing a detail during fluoroscopy that I wish to roentgenograph, I limit the interesting area of the picture on the lower part of the screen and place the ball just in front of it. (Fig. 2.) The screen is then quickly removed and a cassette of convenient size is placed behind the ball, the ball indicating the very centre of the limited picture. The ball keeps the cassette steadily pressed against a thin wooden plate (Fig. 3) framed by the iron screenholder. In this way I am able in a few seconds to accurately adjust a plate of convenient size onto the sharply limited area of the screen; a supply of cassettes always being ready to hand in a leaden box close to the fluoroscopic apparatus.

The X-ray tube is surrounded by an adequate layer of lead and leadrubber, and the screen is covered with leadglass, protecting effectively against the rays used at

the fluoroscopy. At the radiography the examinator retires behind a leaden wall. The above-mentioned X-ray examination can, in this way, be made without danger to the radiologist.

This ball-indicator on the screen has been very useful for the development of our technic for X-ray examination of the stomach and duodenum. Through an immediate exposure of an image limited at the fluoroscopy I am enabled to obtain the best possible roentgenogram at the very moment when the picture offers the most appropriate opportunity of observing the alteration that I wish to study.

This technic demands less and smaller plates than the method of using big series of plates in order to find the most instructive pictures. I also think that the combination of roentgenography and fluoroscopy, performed in this way, is the most appropriate method of making an X-ray examination of the stomach and the duodenum.

Summary

The article describes a new construction for centering and fixation of small plates on the place of a limited picture on the screen by vertical fluoroscopy.

The fluoroscopic screen is supported by an iron holder, framing a thin wooden plate. Guides are placed both on the right and the left side of the holder, and these are connected with each other by a thin, horizontal steel wire, kept tense by a spring and movable vertically on the guides. A wooden ball is movable on the wire laterally. When a picture is limited for roentgenography by the fluoroscopy, the ball is placed just in front of it, the screen is removed and a cassette of convenient size is put behind the ball, which presses the cassette against the wooden plate framed by the screenholder. By this arrangement it is possible to take sharply limited pictures on small plates very speedily during the vertical fluoroscopy.

Microscopic Examination of the Mucous Membrane of the Nose on Patients under Treatment for Lupus Vulgaris with Universal Arc-light Baths

by

K. A. Heiberg and *Ove Strandberg*
Histologist at the Finsen Med. L. I. — Head of the Ear-Nose-and Throat Departement

At the Finsen Med. Light Institution experience has shown in certain important fields the power of universal coal arc-light baths to cure Tuberculosis.[1]

As has been mentioned before, patients with Lupus vulgaris on the mucous membrane of the nose are often not merely treated with universal arc-light baths but also treated with Turbinectomia inferior. While working with this, the attention of the department was drawn to the fact that these numerous excisions, carried out to a therapeutic end, regarded as material, could hardly be expected better in the direction of elucidating the microscopic picture of the healing that takes place under this form of light effect. Many of these operations were, namely, carried out on patients who had *merely* got the light baths, without the local treatment, and by whom there was also an amelioration of the mucous membrane disease, but where, in one place or the other, there remained an affection which it was considered more time-saving to remove by operation, rather than let the patient wait till everything should have vanished.

The *advantages* of the examination of the material mentioned below, which, for by far the greater part, arises from the mucous membrane of Conchia inferior, are evident, in so far as the so-called »local light-or-warmth effect» cannot here, surely, be imagined to have any in-

[1] Cf. Axel Reyn and N. P. Ernst: On the use of artificial Light baths in lupus vulgaris and surgical tuberculosis. Hospitalstidende 1917 —

and the same: The results of the treatment with artificial chemical light baths in lupus vulgaris and surgical tuberculosis. Ugeskrift for Læger 18—20. 1918 (& "Strahlentherapie" 1919).

Ove Strandberg: The use of the universal Light bath in Rhino-Laryngology. Hospitalstidende No. 7. 1918 (& "Strahlentherapie" 1919).

fluence worth mentioning, whereas by many other localisations one might perhaps conceive it as co-operative, even though many circumstances prove it to be by no means final. But, at the same time, hardly any other localisation provides an object — and just from the human being — so profuse and under the comparatively same conditions as exactly the Conchia inferior.

The mucous membrane of the nose being, as a rule, very slow to react to these therapeutics, one may at the outset take it for granted that one will have to face changes of small intensity, and it will probably require a larger material before these changes may be discernible from certain spontaneous »healing-pictures», — if it may be allowed to give to these latter this somewhat pretentious name. Structures in this direction occur nevertheless, even though they are but little conspicuous, and must therefore be mentioned.

In the estimation of the reparative changes due to the influence of the universal arc-light bath it is, on the whole, in many respects well not to be reduced to experimentations on animals, where the localisations will often be other, and where the way of reaction of the organism (we are here thinking of the lupine structure) and its tempi of reaction are not the same. Moreover, it holds good for experimentations on animals that the dose cannot go side by side with that in use, with a therapeutic view, on human beings, any more that it can ever rest on so wide an experience or far-reaching use as that which already lies behind the therapeutics now in use at the Finsen Med. Light Institution.

By the examination of the material mentioned, one has, on the other hand, to struggle with varied *difficulties*. Thus there will, as a rule, be only one, or at the most a couple of excisions from each patient; for that very reason it will be necessary to sum up the picture of the different excisions.

The cases react, however, as the clinical experience shows, very differently to the treatment, so that, in other words, the duration and strength of this treatment alone offers some guidance. And, finally, the period of the last dose in connection with the period of the excision has been so varied that the number of baths alone — without statement of their grouping — gives no quite exhaustive enlightenment and impedes the comparative estimate. The baths have even been spread over varied spans of time. Amongst the difficulties must also be counted that here one stands evidently in face of those on universal arc-light bath slowly reacting localisations, where the conditions of the area are peculiar.

In the above we just mentioned »the spontaneous healing-pictures», by which, then, we refer to the histologic pictures of a lupus vulgaris of the mucous membrane of the nose, showing certain scattered signs

of healing, without having undergone treatment. Even though the histologic picture of this always sporadic and half-finished spontaneous attempt at healing of the mucous membrane of the nose has certain points of resemblance with a similar picture found in the skin, it requires a more exhaustive investigation, the more so, as even that of the skin is, more often than not, neglected a good deal, see UNNA's statement 1894, and the knowledge of this is necessary in order to understand part of the difficulties our examination meets with and the allowances which must be made.

The frequency with which one meets with certain pictures in the direction of spontaneous healing of the mucous membrane of the nose is, we are pretty sure, greater than one, as a rule, is accustomed to reckon with.

If — based on what has been traced — one has to nearer specify how the spontaneous healing-pictures of a lupus vulgaris on the mucous membrane of the nose, histologically seen, arise, this may be done in different ways.

1.) The tubercle may be turned into an almost complete complex of giant-cells. Regarding the skin, UNNA has pointed out how long this »final form» may remain unaltered. After the lapse of decades, the same picture, which one meets with after a few months, may still be found.

2.) In the tubercle may appear ten cells, and, to judge from the shape, all sorts of transitions between these and epitheloid cells are there. Secondly, the newly formed fibrous tissue undergoes the same phases one generally meets with in the forming of a cicatrix.

3.) The forming of the fibrous tissue may start from a central necrosis in the tubercle, and this occurs probably more frequently in the mucous membrane of the nose than in the skin.

4.) The healing may be brought about simply by resorption of the cell-infiltration (UNNA, it is true, maintained, at one time, with regard to the skin that this was not possible, and that the healing-process always takes place through the forming of fibrous tissue; but this cannot be upheld, as there is a form of spontaneous necrobiosis, which LEWANDOWSKY very strikingly describes by saying that the tissue dies away, the cells loose little by little shape and colour, become as it were diluted and loose the ability to colour).

5.) The healing may finally take place through a process which, it is true, can and will have some resemblance to the above mentioned, but where the most salient and above all else predominant feature is the very strong lymphoid-infiltration. There may indeed be round-cells too in the picture mentioned under the former head, but not approxi-

mately in the same proportion as here, where they are quite distinct and characteristic, as the plasmolysis and the remaining necrobiosis of the cells, are so to say, eclipsed to the investigator in face of the mightiness of the round-cell invasion; and by this strong »positive Lymphocyttaxis» there is evidently no question of a phase on the way to the above mentioned picture, but it may be found both in earlier and later stages.

When the process is very far advanced, its chief characteristic is that the epitheloid cells and the giant-cells have completely burst asunder, but the necrobiosis of the giant-cells may still be very conspicuous. The particularly strong accumulation of altogether predominant mono-nuclear round-cells inside the tubercles of the lupine mucous membrane of the nose is rare, though, *outside the light bath treatment* we are going to mention, whereas the appearance of some round-cells — often poly-nuclear — is more frequent. But the fact that there may be found something, at least, in the direction of these pictures, impedes, of course, the examination, when the less pronounced results of the light treatment have to be weighed off.

That the more subtle limitation of the healing-pictures is a difficult affair, is, as has been said, clear beforehand to him who, through examinations of many thousands of histological preparations from lupine structures, has foreknowledge of the question.

For the sake of completeness we beg to point out that our examinations deal solely with the effect of the *universal* coal arc-light bath, and that the local light-treatment — the effect of which has been particularly described by Jansen — does not invite to closer comparison with the effects of the universal light bath, owing to the strongly inflammatory effect of the local treatment, and its altogether acute character with progression in layers during the repeated sittings.

*

Now on examining the different structural dissimilarities, which seem to yield supports for a difference between the preparations from those treated with light (apart from those later mentioned patients treated very long) and the preparations under control from non-treated disturbances in the picture of the tubercles showed, it is true, pretty soon during the treatment, and, moreover, there seemed to be a turning in form of more abundant decay than one generally meets with in the histologic picture of lupus with this localisation. But it very soon became clear that the difficulty of rendering a reliable account of the earlier stages was too great, because at the different attempts at classification the transitions were altogether too numerous. — so that however com-

modious it might be, it won't do, as already stated, to define the histologic picture of a non-treated lupus of the mucous membrane of the nose as always having the appearance of an »uninjured» group of epitheloid cells, or an appearance in some measure near it; for that the habit of this reaction of cells is too varied and in too high a degree subject to different changes, where the limits, qualitatively and quantitatively, with no certainty may be drawn from really progressing involution-phenomena.

As characteristics one might, however, maintain that in histologic preparations from treated cases, the giant-cells and almost complete »giant-cell tubercles» appeared much more rarely. These latter are perhaps here most ready for destruction, as they already represent an involution (see above).

Regarding tubercles in »the transition of fibrous tissue», they appeared almost equally often in treated and non-treated cases (ca. 20 %), whilst in the treated were rather fewer strongly developed pictures of tubercles with central necrosis than one sees in non-treated cases.

Cases with *stronger* plasmolysis and *stronger* round-cell infiltrations were indeed observed in the treated cases; meanwhile none of these processes appeared (in the above-mentioned degree of strength) often enough to play an important part in the more summary treatment of results from the primary investigations, where the cases, treated very long, were left out.

General survey of "giant-cell tubercles" and giant-cell structure.

	Appearance of complete giant-cell tubercles		Appearance of more giant-cells		Appearance of one single giant-cell		Appearance of epitheloid cells alone	
	Number of sittings	%	Number of sittings	%	Number of sittings	%	Number of sittings	%
Mucous membrane of the nose with lupine structure from 50 cases[1] treated with *universal arc-light baths*	7	14	7	14	4	8	32	64 !
	36 %							
Mucous membrane of the nose with lupine structure from 75 non-treated control cases	19	25	24	32	6	8	26	35
	65 %							

[1] In the summing-up of material later on, some more than these 50 cases have been added; there is here a question of 15 later cases, chosen on account of their long treatment, which only serve to further confirm what is here stated.

The above-mentioned differences in the appearance of giant-cells and giant-cell tubercles in treated and non-treated cases is illustrated by the schedule below, which comprises the examination of preparations from 50 patients with lupus vulgaris of the mucous membrane of the nose, treated with universal arc-light baths, and from 75 patients (control cases) with the same disease, but non-treated.

As will be seen from the schedule, complete giant-cell tubercles and also giant-cell structure appear more frequently in non-treated than in treated cases.

On a closer analysis of the 7 cases, where, in spite of treatment with universal arc-light baths, tolerably well preserved giant-cell tubercles were still to be found, it was seen that none of these had undergone a really long treatment.

In the above, then, we have stated more summarily the result of our first examination of the primary material, in order to find out to what a degree the lines of development might be drawn through it, and to see how much was to be found on the way towards the final goal, the healing indicated by Dr. STRANDBERG.

The results are, of course, not to be understood as if they were of final validity, but they are an outcome of our having compared material examined to nearly the same extent, with almost the same intensity, which makes it fit for reciprocal comparison.

*

Earlier in this publication we have examined preparations from all the patients who, under a certain period, have been treated with light baths, and where excision was stated.

Later, as already mentioned, more have been added to these (15), emanating from a later period, and where the treatment has been particularly long when an excision was made.

Now we shall pass on to the description of the histologic picture in preparations from these *very long* treated patients.

In the above are indicated number of ways the healing-process might follow; and whilst »the spontaneous healing-processes» with their, as usual, not half-done work and their always half-finished appearance seem to follow the three courses first mentioned, it was evident that the *light bath treated cases* followed the last but one, and the last perhaps in particular, so that the »swallowing-up» of the tubercles by round-cells, and their necrobiosis seemed especially to augment the longer the treatment went on, and the more baths that were given.

We succeeded in noting regressive changes so fairly on the way towards the picture of final healing that one has a right to maintain

that the next step will not be distinguishable, but that one stands in reality in face of the last discernible stage, before complete healing was a fact (this, too, we have had the opportunity of examining microscopically, but it falls outside the frame of this treatise).

The tubercle cell-groups showed general retrograde movement: decomposition all over. It is not in a single place, or in some few tubercles one meets with this — it is a common fate overtaking all specific reaction tissue, though not always in quite the same manner.

Maybe that now already, in certain cases, the effect of rather more than 50 *lately* given Baths, may be observed with some certainty on the tissue, sometimes more especially as a greater round-cell invasion, now and then more in the shape of augmented plasmolysis and decomposition, which would answer well to the histologic picture of the more advanced results from longer treatment.

In order to throw light on how many arc-light baths the patients in the material in question have got, we bring here the following skeleton-like summary. (Several excisions from the same period and the same patient are only counted as one).

The following number of excisions treated with the following number of universal arc-light baths:

Number of excisions	Number of universal arc-light baths
25	15—49
20	50—100
7	101—150
9	150—250
4	300—550

As one may see, there has below been given 5 of the last group but one, and the whole of the last group. The limited space has caused the exemplification to be abbreviated. In the first and second of the stated cases alone, it is a little more wordy.

In some of the cases we shall see that the changes were found even where the treatment is of an earlier date: the healing process often goes on, it is true, after the treatment has ceased. On the other hand, it seems, there may, start a new growth of the disease during a pause as long as final healing is not at hand.

P. J. No. 2836. Has all in all got 179 baths stretched over the following period:

January 1914—March 1914 32 baths December 1915—March 1916 79 baths
November 1917—March 1918 68 »

Excision $^6/_3$, 1918. In the first sections there is seen a rather deep-seated, pretty strongly round-cell-infiltrated, in some incisions even plasmolytic, tubercle.

Later one notices a tubercle with a similar deep seat, quite satiated with round-

cells. Nearer the surface we notice strongly round-cell-infiltrated parts of epitheloid cells, in two places, moreover, with fibrous tissue transition.

In later sections there are found partly twoplaces with approaching fibrous tissue, partly in one place in the round-cells à fragment of irregular form, a remnant of a group of epitheloid cells.

Still later sections give essentially a similar picture, in one place is also found central necrosis in a tubercle otherwise somewhat round-cell-infiltrated.

189 sections have been examined in all.

M. L. No. 2448. Has got in all 202 baths from $^{8}/_{6}$ 1916—$^{17}/_{3}$ 1917.

Excision $^{7}/_{9}$, 1917. Close to the surface one sees not only a small, round-cell-invaded, sharply defined heap of epitheloid cells, wherein slight central necrosis, but bordering on this is a larger part, where the tuberculous structure is but just discernible. A little further the same fact is noticed.

In another section in the series it was noted, too, that the limit of what can at all be defined as tuberculous structure has been reached; a little later on, and one will not then be able to see what was there before, since as the guidance, given through the presence of tolerably preserved tubercles, will then be lost. In all 162 sections have been examined.

G. F. V. No. 2265. Has got in all 223 baths divided over the following period:

October 1914 — February 1915	62 baths	January 1917 — February 1917	21 baths
February 1915 — May 1915	30 »	September 1917 — April 1917	28 »
October 1915 — December 1915	28 »	June 1918 — July 1918	19 »
May 1916 — May 1916	16 »	March 1919 — May 1919	19 »

Excision $^{22}/_{5}$ 1919. Tubercle structure with strong round-cell invasion. — Plasmolytic or necrobiotic tubercles. 46 sections examined.

P. B. No. 2470. Has got in all 226 baths spread over the following period:

August 1916 — May 1917	224 baths	June 1918	2 baths

Excision $^{6}/_{7}$ 1918. Round-cell invasion in tubercle structure; moreover plasmolysis and fibrous tissue transitions. 82 examined sections.

B. O. No. 2089. Has got in all 237 baths spread over the following period:

December 1915 — July 1916,	158 baths	September 1916 — December 1916,	79 baths.

Excision $^{21}/_{6}$ 1917. Round-cells in tubercles, decomposition, transition of fibrous tissue. 57 sections in all have been examined.

F. J. No. 2238. Has got in all 314 baths stretched over the following period:

May 1914 — December	126 baths	From $^{12}/_{4}$ 1918	11 baths
September 1915 — November	177 »		

Excision $^{6}/_{5}$ 1918. The tubercles show overflow of round-cells and dissolution. 65 sections in all have been examined.

H. D. No. 2399. Has got in all 340 baths stretched over the following period:

December	1915—May 1917,	323 baths	December	1918	2 baths
October	1917	15 »			

Excision $^{11}/_{12}$ 1918. Slight round-cell invasion and epitheloid part with diffuse round-cell infiltration. Altogether ca. 50 sections have been examined.

P. L. No. 1301. Has got in all 363 baths spread over the following period:

December	1914—Febr.	1916	279 baths	September	1917—Nov.	1917	25 baths
February	1917—June	1917	42 »	Februari	1918—Oct.	1918	17 »

Excision $^{7}/_{2}$ 1919. One relatively well preserved tubercle, as one may call it in spite of central decay, is to be seen; in other sections dissoluted tubercle structure. In all ca. 40 sections have been examined.

K. S. No. 2224. Has got in all 539 baths stretched over the following period:

March	1914—Dec.	1914	203	baths	February	1917—March	1917	23	baths
April	1915—Oct.	1915	87	»	April	1917—July	1917	56	»
November	1915—Dec.	1915	15	»	November	1917—Nov.	1917	20	»
January	1916—July	1916	36	»	April	1918—July	1918	36	»
September	1916—Dec.	1916	63	»					

Excision $^{9}/_{7}$ 1919. Tubercle structure with abundant round-cell invasion. — Remnants of Tubercles. 175 sections examined.

Summary

1) Under the treatment with the universal coal arc-light baths reparative changes take place in Lupus vulgaris in the mucous membrane of the nose.

2) The manner in which healing is brought about under the treatment with light baths, is, histologically seen, even qualitatively different from the picture one meets with in the feeble, spontaneous attempts at healing of the lupus vulgaris of the mucous membrane of the nose.

3) Moreover, these examinations have shown that the healing of the mucous membrane of the nose in lupus vulgaris, which can be clinically proved (see the publication by STRANDBERG, referred to in another place in this treatise) under the above-mentioned universal light bath treatment, is not a merely apparent healing, but a real healing process, histologically proved.

FROM THE RADIOLOGICAL DEPARTMENT OF THE UNIVERSITY HOSPITAL, LUND
CHIEF: LARS EDLING, M. D.

On Plastic Means of Application in Radium Therapy

by

Lars Edling, M. D.
Lecturer in Medical Radiology in the University of Lund

Introduction

During the active period of development of modern radium therapy up to the present it has principally been the methods of dosing and filtering that have attracted general interest, while the technique of application has only slowly and in quite recent years begun to appear as a factor of importance. How little this latter question has kept pace with the general development of radium technique will be clearly shown by a critical examination of the methods of application hitherto described in the literature of the subject.

The principal demands which should be made upon this part of the technique at the present stage of medical knowledge of radium treatment will perhaps be most clearly recognised if we imagine that there exists a universally practicable, ideal method of application, which will then possess the following characteristics:

First and foremost this method must ensure an *exact* application, i. e. an exact correspondence of the radium preparation to the various forms and parts of the tumour in question. It must also be *reliable,* and should guarantee the continued application of the radium during the whole time of treatment, so that it is not displaced by movements of the patient, secretion from wound surfaces, etc.

In the next place such a method of application should permit of the use of *filters* and *protective appliances* of various kinds for surrounding tissues not affected, as well as of simultaneous irradiation from different sides *(cross-fire treatment),* and should further conveniently and reliably allow of all kinds of *modifications of the focal distance* in the various parts of the area to be treated.

The method should be *painless*, or at least not associated with too great inconvenience for the patient. The risk of serious *bleeding*, of lesion of the tissues and thus perhaps causing *metastasis*, etc. should be excluded, and also irritation of the tumour whether purely *mechanical* or caused by abundant *formation of secondary rays*.

From an *economical* stand-point a universally practicable method of application *should not involve too great expense*, so that it may be suitable also for *treatment on a large scale*. *The use of material*, the necessity for *trained assistants* or *costly technical aid* should be reduced to a minimum. Finally, the method should be *simple* and *convenient* to carry out, and should not require *lengthy preparations*.

The methods of application which have come into use during the past few years may be divided into the following main groups:

(1) Application by means of sticking-plaster (only upon the skin).

(2) Manual application (both on superficial cutaneous tumours and on various tumours of different mucous membranes.

(3) Application by means of probes, catheters, etc. (in certain membranous regions, e. g. the oesophagus, the urethra, the uterus, the nasal cavity).

(4) Application by means of special auxiliary instruments, purposely prepared for special cases and regions of the body (all kinds of tumours of different mucous membranes.)

(5) Application in the operative way (radio-puncture, emanation needles of STEVENSON, radium operations).

If, without entering into details, we attempted to arrive at a general valuation of these main methods from the point of view of the demands formulated above, and under the guidance of experience, the result might be summarised somewhat in the following manner:

(1) *The sticking-plaster method*. This is generally sufficient in simpler applications of not too large or heavy radium tubes, on cutaneous tumours without ulceration and without complicated exterior form. But it is less satisfactory, on the other hand, when *very heavy apparatuses or many capsules* at a time are to be applied, especially if the skin surface in question has an irregular form or may very easily be displaced.

On damp skin surfaces or secreting ulcers the plasters cannot be employed; and on very delicate skin their use should also be avoided, since they may easily cause irritation.

(2) *Manual application* is excellent, and affords an extremely satisfactory control of the position of the radium, on the skin and in various membranous regions; in other places, however, e. g. the pharynx, the rectum, this method is less satisfactory. In protracted irradiations it is always very tiring for both nurses and patients, and it has the disadvantage of requiring specially trained attendants.

(3) In certain membranous regions (the urethra, the oesophagus) the *application* of the radium *by means of probes and other cylindrical instruments* is the only method that has hitherto been used, and is practically the only one conceivable.

(4) Of the *special contrivances* constructed for tumours of the mucous membranes some are more, others less satisfactory. Among the former must be counted the holders for tumours of the mouth, invented by STICKER, the palate plates of WICKHAM and DEGRAIS and FORSSELL, the »fixator», of ALBANUS; but the latter category is by far the more numerous. In general, it must be said of these instruments that they are complicated and little calculated to suit different cases, and that they are expensive in working since, as a rule, the apparatus has to be set up separately for each patient.

(5) Of the *»operative» modes of application* the ordinary radio-puncture should be reserved for circumscribed solid tumours which are accessible from without. Radium operations (excochleations etc.) should, on account of the risk of metastasis, be carried out only in urgent cases. Finally the application by means of emanation needles has inaugurated quite a new developement in the domain of radium therapy but requires a very great amount of radium and is, therefore, not yet possible to realize in every institute.

It should be clear from the above that none of the methods hitherto used in the application of radium even approximately fulfils the above conditions for a generally practicable method. It must therefore be considerated extremely desirable to obtain a means of application which, on the one hand, could guarantee satisfactory fixing of the radium tubes, but, on the other, could afford an unchangeable and at the same time easily applicable medium which will ensure the fulfilment of the demands both for a good secondary ray filter and for the possibility of modifying the radium distance at will.

A. General Part

1. Origin and Development of the Plastic Method of Application

The first idea of using a plastic material for fixing the radium preparation on to the place of treatment occured to me in the beginning of 1910, in connexion with the treatment of a case of tonsillar sarcoma. At that time I used to apply the radium by means of the method which has been described above as the manual, and consequently the patient

himself had to hold it against the tumour in the throat by means of a handle. The difficulties associated with this means of application — the vomiting reflexes, the salivation, and the difficulty of properly controlling the position of the radium capsule — led me to think that a plastic paste which would stiffen at bodily temperature, and could be moulded on to the tumour and fastened in the mouth in some way, ought to give a better fixing of the radium upon the desired spot. I made this suggestion at the end of a paper which I read on the case in question at the third International Congress for Physiotherapy at Paris in 1910, but various circumstances prevented the carrying out of the idea during the years immediately following.

It was not until five years later that I was compelled once more to take up the idea on account of lack of assistants and suitable premises for radium treatment according to the old method. The case then in question was a cancer of the upper jaw, where resection had been carried out and radium treatment of the remains of the tumour in the large resection cavity was to be performed. For this purpose I used the plastic composition »Trilbi» employed by dentists. The radium tubes, surrounded by a filter-capsule of lead, were imbedded in this mass and introduced into the cavity, which was quite filled with the plastic material so that a complete cast was taken. This »radium-prothesis» was, moreover, held in place by a so-called palate-spoon of metal, which was filled with paste and fixed between the teeth.

In the next case, a *giant-cell sarcoma* of the hard palate, I filled the spoon with soft paste and thus prepared an impression of the palate together with the tumour. The affected area which consequently in the cast looked like a depression, was warmed up again and the tubes and filters were pressed into the mass, which was then smoothed over and thereby made to serve as a secondary filter. This contrivance was then applied once more to the palate, the teeth impressions that remained guaranteeing that the radium was applied to the right spot.

I afterwards tried to combine ordinary protheses of hard rubber with additional parts of plastic material, which were added *in situ* over the tumour area itself and in which the radium tubes were imbedded. It proved, however, that this device involved no advantage, but rather a complication of the method.

After several experiments, which, as a matter of fact, all stranded upon the use of an unsuitable plastic composition, I finally hit upon the expedient of *arranging the fixing apparatus solely by means of the impression compound.* The principle of this gradually developed method may be stated thus: *An impression of the tumour and its immediate neighbourhood is prepared out of the plastic material. On the outside of this cast the*

radium tubes and filters are attached according to the indications furnished by the impression, the plastic substance itself serving partly as a secondary filter and partly as a means of regulating the distance of irradiation. Finally both the protective arrangements and the actual fixing of the apparatus are secured by the aid of the plastic substance.

The method was at first used only for tumours in the cavity of the mouth, afterwards for other tumours, for example in the orbita after exenteration for cancer and sarcoma, and finally also in tumours of the face, the pharynx, the genital organs, etc. At the beginning of 1917 I gave a short preliminary account of the method in the *Münch. Med. Wochenschrift*, and afterwards a detailed description in a larger work published in 1918, of which the present paper is a condensed and somewhat revised edition.

From the autumn of 1915, when the method was communicated by me to Prof. G. FORSSELL, head of the well-known Radium Home in Stockholm, it has been the object of independent developement at that institute, the results of which were communicated in 1917 in a work of E. BERVEN. To this work I shall repeatedly recur in the following pages.

However, I must first touch upon certain earlier notices of which I had no knowledge before the beginning of the work mentioned above, and from which it appears that a plastic substance had been used in other quarters also in radium applications of certain kinds, although the method does not seem to have attracted any attention worth mentioning.

Thus WICKHAM and DEGRAIS in their second edition (1912) have already recommended in the case of tumours of the jaw and palate the use of arrangements (see p. 220, fig. 82) which consist of an ordinary palate-plate of hard rubber or wax, to which the radium tubes are attached by means of *godhiva*, an impression compound generally used in France. This is the combined device which, as has been mentioned above, I tried, but abandoned as unsatisfactory.

At the point of time when my original work on this topic was published (Sept. 1918), I had not been able to find in the English or American medical works any trace suggesting the use of plastic material in radium therapeutics in these lands. Last year, however, there appeared in the Archives of Radiology a most interesting report by FAILLA of the radium technique at the Memorial Hospital of New York, where detailed statements are made of the use of dental compounds for the application of radium.

It seems that such compound moulds in America were originally used by Dr JANEWAY, of the said Hospital, in the following way. A mould is taken of the tumour in question, the area that corresponds to the lesion is marked on the impression with ink. In this area grooves are

made with a hot tool, where the radium tubes are placed, and then are filled out with paraffine.

FAILLA calls attention to the advantage ensured by this method that the radioactive source is distributed over the area to be treated exactly as we wish it, and remains in the same position for the duration of the application. That is especially important in treating tongue cases because of the mobility of this organ. The method makes it possible also to irradiate tonsillar tumours, by attaching the tubes to a lead holder, which is properly bent and then fastened to a compound mould which fits between the teeth.

The tubes are placed 3 mm. from the impression surface, or 5 mm. in using gamma rays and lead filters. FAILLA states that the absorbing power of the compound is such that 1 cm. will reduce the radiation of a silver tube 0.5 mm. thick by 40 per cent., and that of a lead filter 2 mm. thick, containing such tubes, by 28 per cent.

For the protection of normal tissue lead plates, 2 or 3 mm. thick, are used and fastened with paraffine to the applicator. The doses are modified according to the extent and curvature of the treating surface.

The use of compound moulds at the Memorial Hospital seems, however, to be limited to the lesions just named. A universal use in external cases etc. FAILLA seems not to know. It is a curious coincidence, though, that this method should be invented and applied for such a purpose at nearly the same time in two hospitals quite independent of another.

Further, I have found in the report of HAYWARD PINCH from the Radium Institute of London, 1919, a statement that seems to indicate that the use of dental modelling compounds in radium therapy is known in England. PINCH too, however, has used it only in a very limited degree; indeed, he only mentions it in cases of tumours of the jaws, where a mould of the affected area is made and removed from the mouth, whereupon the radium tube is inserted in a groove in the mould which then is replaced over the affected site.

In Germany, again, ALBANUS in his development application contrivances for radium treatment in the upper organs of respiration has made a fundamental use of »protheses» of plastic substance meant especially for irradiation of tumours of the mouth. From his work it appears that he prepares by means of a compound an impression of the upper and lower jaws, which serves to fix the whole, and then provides this apparatus with an off-shoot through the opening of the mouth, which facilitates removal after the irradiation. Upon this »prothesis» he fixes the radium by means of firmly attached pieces of sticking-plaster; sometimes it is fixed upon a specially hollowed-out projection, the length and form of which is adapted to the position of the tumour (on the

root or sides of the tongue, the walls of the pharynx, the tonsillar region). This projection is not made until after the prothesis proper is ready, and is prepared by heating and re-forming the corresponding part of the latter. It must fit well and must not exert undue pressure, for fear of causing vomiting reflexions. Finally the radium capsules are secured on the outside of the check with strong wires.

These experiments of ALBANUS do not seem to have aroused any attention in Germany since they are nowhere quoted; only WICKMAN, who worked with ALBANUS, refers to them. In March, 1917, when I published my preliminary account, ALBANUS' writings were unknown to me. Later, in a short notice he has claimed priority over me in the matter of radium treatment by means of »prothesis» of plastic material; nor do I dispute his claim in so far as the actual use of plastic material in irradiations of the pharynx and the cavity of the mouth is concerned. From the above-given summary of his works, however, it will be clear that his method in the case in question is quite different from mine, since ALBANUS simply fastens the radium preparation by means of sticking-plaster onto a hollowed-out projection of the »prothesis». The use of the plastic mass as a secondary filter and as a means of regulating the radium distance he does not recognise at all, nor yet the advantage of fixing the radium preparation by means of the mass itself. Moreover, his technical instructions are by no means exhaustive even so far as the above-mentioned membranous regions are concerned. Still less has ALBANUS any idea of the manifold uses of the plastic mass in other departments of radium therapy. It should, therefore, be incontestable that, so far as the fully worked-out and generally practicable plastic method of application is concerned, priority is to be ascribed to me.

Further, we find in WETTERER (Handbuch, II Auflage) a description and recommendation of the process given by WICKHAM and DEGRAIS for the treatment of tumours of the jaw or the palate. WETTERER's use of the plastic method is, therefore, extremely limited, and cannot be supposed to imply any independent work in this direction, since in the case of tumours in the palatine arches and tonsils he recommends WICKHAM and DEGRAIS' antiquated metal radium holders instead of the ALBANUS method of prothesis which lay so near to hand.

STICKER also in a case of cancer of the lower jaw has recently used a plastic substance in the shape of a conical block for radium application, a channel being bored through for the radium tube.

Of a later date are further BAISCH's experiments in embedding the radium preparation in pellets of paraffin or wax of 1 $^1/_2$ cm. thickness, with a view to thus securing, with application in the vagina, a suitable distance between the radium and the recto-vaginal septum. This sub-

stance, however, has little of a plastic character about it, and, moreover, BAISCH seems to confine himself to these pellet-shaped appliances, which only serve the above-mentioned object and cannot be developed in accordance with the form of the different tumour areas.

Finally, we may mention WERNER who, in vulvar cancer, has embedded the radium capsules with their filters in a large block of plastilina, which he moulds to the shape of the locality in question and attaches by means of strips of sticking-plaster and bandages. Plastilina, however, as BERVEN has rightly pointed out, is unsuitable for this purpose, since it has a soft consistency at bodily temperature and therefore gives a bad fixation.

The term »prothesis» which ALBANUS uses for a cast such as has just been described as a means of application is, in this sense, inadequate, since an apparatus of this kind is not a substitute for anything, but rather constitutes something new, a further contribution. I propose therefore to exchange this word for the word »*applicator*», which is both satisfactory linguistically and easy to pronounce, and further gives a definite idea of the object of the method. Lately, as I have seen, FAILLA has used the identical name for these contrivances.

2. Chemical and Physical Analysis

In order to answer the demands of radium therapeutics the plastic compound must fulfil certain conditions, the most important of which have already been stated by ALBANUS. It must, for instance, ***easily soften*** with heat, but ***rapidly harden*** again on cooling, and must also maintain its hard consistency at bodily temperature (e. g. in the cavity of the mouth). Further, the material in its soft state must be extremely ***ductile*** and possess a high degree of ***plasticity***, which should preferably not be lost until after it has been heated several times, so that the substance can be used repeatedly. Finally, it should be absolutely ***homogeneous***, so as to take a really delicate and detailed impression.

With reference to these conditions I have examined the following dental compounds:

(1) KERR Perfection Impression Compound (Detroit Dental Manufacturing Co., Detroit, U. S. A.).

(2) HARVARD Präzisions Abdruckmasse (RICHTER und HOFFMAN, HARVARD G. m. b. H., Berlin W, 10).

(3) S. S. WHITE Modelling Composition (S. S. WHITE Dental Manufacturing Co., U. S. A.).

(4) CROWN Composition (King's) for modelling, taking impressions, etc. (CLAUDIUS ASH and SONS, Ltd., London).

(5) TRILBI Präzisions-Abdruckmasse (RÓNA IMRE, Budapest).

Of these compositions only KERR is well suited to the ends in question. It is dark reddish-brown in colour, is hard and brittle, and extremely fine-grained and homogeneous in substance. It softens at 60° C, has a tough and ductile consistency when heated, but stiffens with great rapidity and adheres very firmly to the object. The impression is very delicate and detailed. The substance can be heated several times without its deteriorating to any great extent.

Other plastic substances are either not delicate enough or else do not keep their hardness sufficiently well at bodily heat, and therefore are less suitable.

In regard to the chemical composition of the plastic substances, for their use as secondary filters it is important to know whether, beside their organic ingredients (wax and resin in various combinations), they also contain inorganic ingredients. The chemical analysis which Professor L. RAMBERG has had the kindness to carry out at my request has in fact shown that they all have a percentage of ***inorganic substance*** which varies between 50 % (KERR) and 57.6 % (HARVARD). This substance virtually consists in them all of ***aluminium-magnesium oxide***, with small additions of silica, ferric oxide, and, in KERR, a little calcium oxide, and is probably constituted of more or less pure modifications of the mineral ***spinel*** (Mg. O, Al_2 O_3).

These metallic ingredients are, from the point of view of radium technique, to be regarded as a great advantage, since aluminium at least is distinguished by giving a relatively inconsiderable secondary radiation; probably the chemically related magnesium behaves in much the same way, although, so far as I am aware, no further researches have been made into this question.

In order to arrive at a certainty as to the filtering properties of the plastic substance and its secondary radiation I have planned a physical analysis which has been carried out at the Lund University Physical Institute by one of the assistants, Mr J. TANDBERG.

In the literature with which I am acquainted I have hitherto found record of only one piece of research in secondary radiation in the case of the filters commonly used in radium therapeutics, namely, the little work of SCHLESINGER and HERSCHFINKEL. These authors have divided the different filters into the four following groups, in accordance with the radiation-values found by them: —

(1) The first group includes ***lead***, which has the greatest secondary radiation, the intensity of which is put = 100.

(2) Next come various ***metals*** — copper, brass, German silver, aluminium — vith secondary radiation-values varying between 60 and 50.

(3) A third group, embracing such substances as ***resin***, ***silk***, ***wool***, ***cotton***, and ***paraffin***, has secondary radiation-values between 50 and 40.

(4) Into the last group come the various kinds of *India rubber*, which have the feeblest secondary radiation, between 35 and 30.

So far as can be gathered from the authors' expressions, it seems here to be a question both of emergence radiation from the anterior wall of the electroscope employed and of incidence radiation from the other walls. Since, further, the increase or diminution in the secondary radiation is calculated only from the rising or falling total ionisation produced by 10 mg. of mesothorium at a distance of 15 cm., it will be seen at once that the secondary ionisation values given cannot be very exact.

In the researches planned by me parallel experiments have everywhere been carried out, partly with the plastic means of application, and partly with the secondary filters most commonly used — rubber, paper, surgical gauze.

These measurements, on account of the numerous sources of fallacy involved, can certainly make no claim to physical exactitude, yet may perhaps be of value for purposes of practical therapeutics. And this all the more since the technical conditions in radium therapeutics vary so much that the same physical postulates can by no means be applied everywhere with the same exactitude.

As *ionisation instrument* has been used an electroscope built according to RUTHERFORD'S instructions, the lower chamber of which is closed only by a piece of thin typing-paper. The electroscope was, moreover, surrounded by a leaden covering 3 mm. thick, and the front wall of the upper chamber was further protected by and extra covering of lead 5 mm. thick. A Dominici radium tube of platinum 0.5 mm. thick and with a radium bromide percentage of about 10 mg. served as radiation source.

In addition to the plastic substance KERR the following were also tested: *glycero-gelatine of zinc*[1], *cofferdam*, completely free of lead, *paper* (yellow Swedish copying-paper n:o 91), and *surgical gauze* of the ordinary quality (in bandage form).

(a). *Measurements of the absorption of the primary radiation of the radium by the different secondary filters.*

The radium tube is placed at a distance of 50 cm. from the front side of the lower chamber. Before this the different secondary filter plates are suspended, cast as nearly as possible in the same form. The inside of the chamber is lined with paper 2 mm. thick, so as to reduce the secondary radiation of the metal wall. Correction for the rays which penetrate the lead covering of the upper chamber is introduced into the absorption curves.

As the figures 1—2 show, the absorption curves both of the older secondary filters and of those introduced by me have a great resemblance to each other; the gauze curve constitutes an exception and is flatter, evi-

[1] Used by me as secondary filter for special cases, where an elastic means of application was to be desired.

dently on account of the smaller percentage of absorbing material. The absorption is quite inconsiderable and varies between 12 and 20 % of the total ionisation (less in the case of the gauze), with the thicknesses of material mostly used in therapy. Had the measurement been applied only to the gamma radiation, the absorption would naturally have been still less.

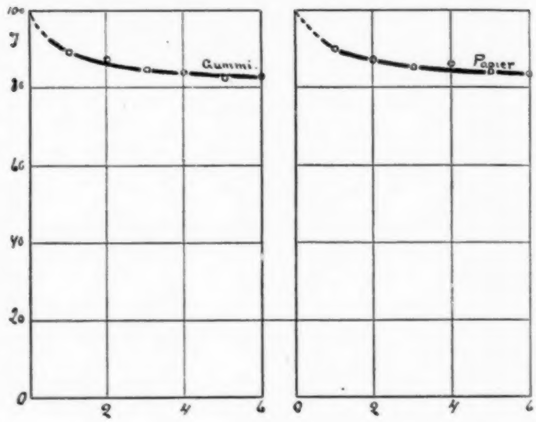


Fig. 1.

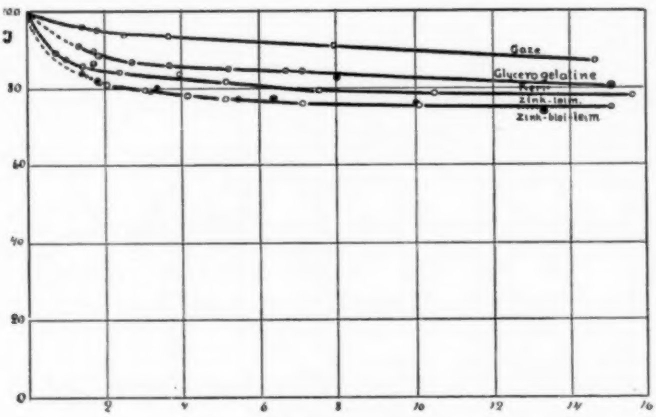


Fig. 2.

(b). *Measurement of the emergence radiation of the different secondary filters.*

As is well known, we distinguish, in regard to the secondary radiation of a body, between the rays which are »reflected» from the surface exposed to the primary radiation (*incidence radiation*, RUTHERFORD) and those which penetrate out from the opposite surface of the body *(emergence radiation)*.

From the standpoint of therapy it is the second of these that chiefly interests us in regard to the secondary radiation of the media of secondary filters, since only this is absorbed by the tissues and has been considered to be the cause of the so-called radium injuries.

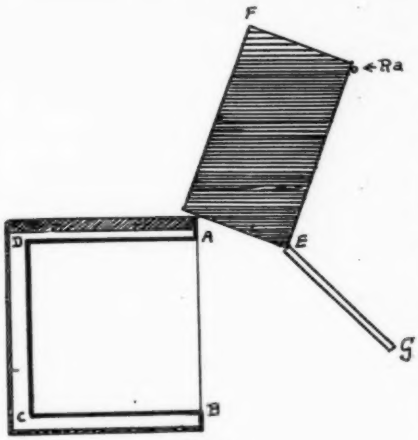


Fig. 3.

The arrangement of the experiments is shown in fig. 3. The leaden block EF is so placed that the primary radiation of the radium tube (Ra) is prevented from invading the ionisation chamber. The secondary radiator EG stands symmetrically in relation both to the radium tube and to the axis of the electroscope, the distance of the latter from the tube and from the ionisation opening being 14 cm. The tube is enveloped in a leaden filter 1 mm. thick, the upper chamber of the electroscope is protected by the leaden covering AD.

The ionisation here measured arises partly from the secondary radiator itself, partly from that portion of the primary radiation which has been able to pass the leaden block, and partly again from the radiation »reflected» from surrounding objects. If we call the measured ionisation h_1, and the last-named component h_0, the ionisation of the secondary radiator is $= h_1 - h_0$ (h_0 can be measured after removal of secondary radiator).

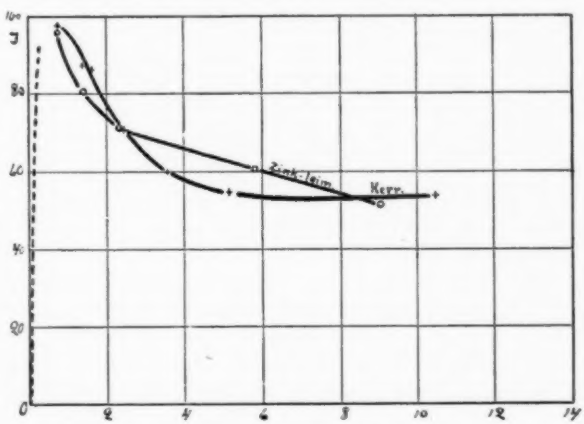


Fig. 4.

As a unit in the measurements we take the emergence radiation of a 1 mm. leaden plate of the size of the secondary radiator (= 100). The total ionisation measured we call h_{Pb} and hence obtain the following expression for the relative ionisation of the secondary radiator:

$$\frac{h_1 - h_0}{h_{Pb} - h_0} . 100$$

which value is inserted in the following curves of the emergence radiation of the different media (see figs. 4, 5, 6).

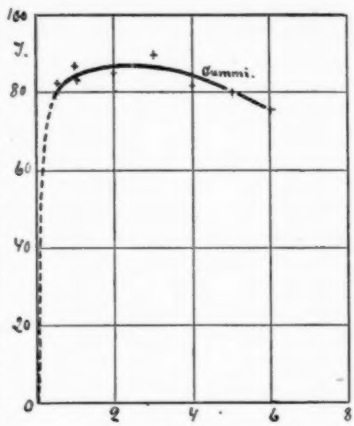


Fig. 5.

All these curves show that the secondary radiation rises rapidly with a thin layer of material, and falls again more slowly with increasing surface thickness. In KERR and glycero-gelatine the maximum is already reached before a thickness of 1 mm. is attained. With a thickness of 5 mm. in the secondary radiator the intensity has again sunk to about 50 % of that of the lead, and afterwards diminishes only slowly, at least as long as the surface thickness is kept within the limits usual in radium therapy. Rubber and paper give similar curves, only their tops have a broad curved shape, corresponding to a surface thickness of 1—3 mm., which is probably due to the absence of metallic ingredients. In the case of the surgical gauze the course of the curve is still more prolonged, its culmination only being reached at a thickness of 8 mm. (this is due to the looser composition of the stuff and its low spec. gravity). Fig. 7 shows the relations between the thickness of the layer of paper or gauze and the number of layers.

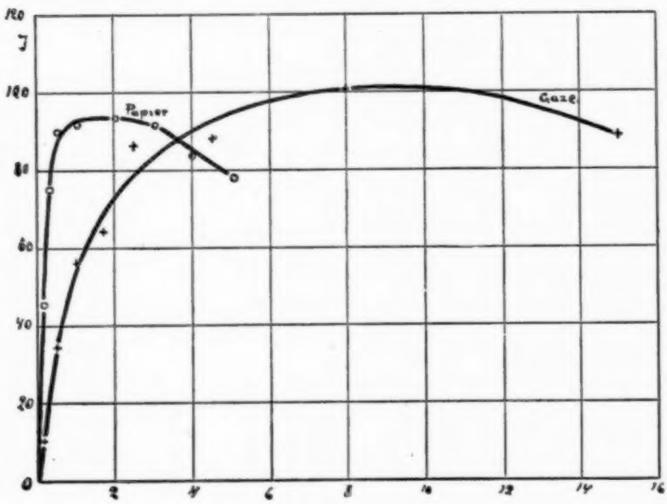


Fig. 6.

The lowest values of secondary radiation are therefore found in KERR; The glycero-gelatine behaves in much the same way. The radiation of

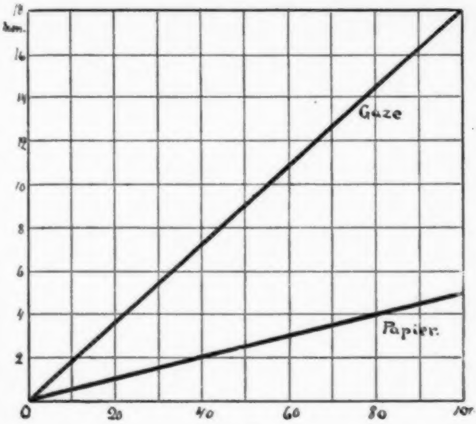


Fig. 7.

the older secondary filters on the other hand, with the thicknesses employed in therapy, lies considerably higher (85—90 % of that of the lead), which, especially in regard to rubber, seems remarkable, and is probably due to the great amount of soft emergence radiation which passes the opening of the ionisation chamber in these experiments, a condition the reverse of that found in the work of SCHLESINGER and HERSCHFINKEL.

In any case the secondary filters used by me give ***no more abundant secondary radiation*** than those formerly in use.

(c) *Measurements of the emergence radiation of combinations of lead filters and various secondary filters.*

Apparatus as in (b), except that at EG are fixed leaden plates of different thicknesses, provided with different secondary filters on the side facing the electroscope. The radium tube is used without any lead filter. As a unit we continue to use the emergence radiation from a leaden plate 1 mm. thick.

As is shown by the curves in fig. 8, an inconsiderable increase of the secondary filter is sufficient to cause a strong reduction of the secondary radiation of the lead, which with the use of *rubber* approaches its minimum (about 50 %) at 1 mm thickness, with *paper* sinks still lower (about 40 %) at 1—2 mm. thickness. The *surgical gauze* curve here as before reveals a deviating course, in that at least 5—6 mm. are necessary before the above reduction in the secondary radiation is reached. This agrees with the statements of CHÉRON and RUBENS-DUVAL, who, in cervical cancer, recommend a corresponding number of layers of gauze (see the reduction curve, fig. 7).

A comparison with the new secondary filters shows (fig. 9) that the plastic substance KERR at 1 mm. surface thickness already causes an absorption of about 80 % of the lead radiation, i. e. a value considerably higher than the foregoing, and that with an increase in the thickness of the compound up to 10—11 mm. the absorption remains nearly constant. The curve shows an almost similar course when *glycero gelatine* is used. If further the thickness of the lead filter is increased to 2—3 mm., the

form of the curve remains practically the same, except that the minimum sinks lower.

All these secondary filters, therefore, may be considered good, but the last discussed seem decidedly to be preferred from the point of view of *quantitative filtration*. In radium therapy, however, there is another important factor to be considered, viz. the influence of *irradiation distance* upon the intensity of the radium light and its distribution in the tissues. In this respect the secondary filters KERR and glycero-gelatine may be described as perfectly satisfactory, since with increasing surface thickness they do not cause any appreciable increase in the secondary radiation.

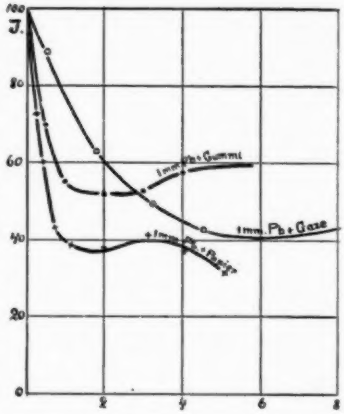


Fig. 8.

The portion of the radiation in question which is already absorbed by very thin layers of the secondary filter must doubtless consist of β-rays of a low degree of hardness (secondary β-rays, EVE; see RUTHERFORD p. 272). The remnant must be composed both of β-secondary-rays and of scattered γ-rays of varying hardness (FLORANCE; see RUTHERFORD p. 284). As to the quantity and penetrance of the rays of this kind these curves naturally afford no information.

Since, however, the soft, easily absorbed (β-) rays which would otherwise have remained in the outer layers of tissue are more strongly absorbed by KERR and glycero-gelatine than by the older secondary filters, the former have also a decided preference from the *qualitative* point of view.

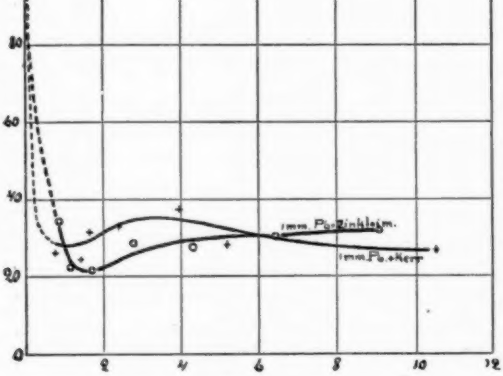


Fig. 9.

Again, in regard to the penetrating remnant of the emergence radiation and its therapeutic value or injuriousness, our experiments seem to lead to an agreement with the opinion of KRÖNIG, suggesting that the radium injuries with high filter therapy are caused by direct over-dosing with γ-rays in the outer layers of tissue. The relatively inconsiderable remains of β-emergence radia-

tion, on the other hand, seem to be of little importance here. Finally, in the matter of the scattered γ-rays, it is evident that at least they cannot be considered as more injurious to the tissues than the primary γ-rays from which they take their origin.

3. General Principles for the Use of the Plastic Method of Application in Radium Therapeutics

The plastic substances are sold in the form of flat cakes which rapidly soften in water of a temperature of about 60° C. For the softening I use an ordinary porcelain dish, which is filled from time to time from a pan of boiling water.

The substance is taken up by means of a spatula, preferably of wood, which does not conduct the heat, and is cut up with a pair of scissors into quantities suitable for the required purpose. In order to prevent the substance from sticking to the fingers or to the tumour area the skin should first be greased with vaseline or paraffin. This is especially necessary in hairy places, for otherwise when the substance has stiffened the hair will come away when the applicator has to be removed. In fact, it is generally best to shave off the beard, pubes hair, etc. beforehand.

During the application the patient takes a sitting position or lies on his back. The latter position is often to be preferred, since the parts of the body to be treated can be more easily brought into repose, and the plastic substance cannot so easily run away.

Usually I first place over the surface to be treated a ***fundamental layer*** of the compound, which serves at one and the same time as ***impression*** and as ***secondary filter,*** and to the thickness of which ***the radium distance*** is adapted. With a little practice one soon learns to judge the approximate thickness by the fingers. The substance is spread out over the surface in question with careful and uniform pressure, is completed, if necessary, with fresh material, and is then rapidly cooled with cold — preferably iced — water, which last process is carried out in outward applications by means of damp compresses in the cavity of the mouth by spraying.

The applicator ought now to be taken off so that one can convince oneself that it fits well and that the impression is exact. Its form can then be cut out and smoothed, the thickness (the radium distance) can be corrected by removing or adding to the substance, and controlled by measurement. Where specially powerful capsules require greater focal distance, a small block of the compound may suitably be added.

All these manipulations are carried out by means of a common knife or similar instrument, heated in a spirit-flame. In order that the applicator shall not soften in the process, the whole should be dipped in cold water from time to time, and finally tested once more so as to ensure that it exactly fits on to the tumour area.

A good impression ought to show on the corresponding side of the applicator a virtual relief map in a negative form, under the guidance of which it becomes possible to apply the radium to the absolutely correct spot. It is convenient first to outline the outer limits of the tumour area with a hot instrument on the radium side of the applicator. In cases where the tumour itself is not visible upon the impression, other means must be used (see below p. 83).

The radium tubes are now attached, if necessary enveloped in filter capsules or else wrapped in tinfoil (BERVEN) in order to protect the surface of the metal. They are attached with tweezers (not with the fingers, to avoid dermatites!) and are fixed in grooves made in the substance by means of a heated tool. According to BERVEN the tubes themselves may also be cautiously heated in the flame, so that they stick fast of their own accord to the applicator. In order to ensure constant control of the number and position of the preparations used, the tubes are provided with threads which hang out of the applicator.

Lead filters are equally easy to attach to the applicator. They should be cut out with scissors, modelled to the desired shape, heated in the flame, and allowed to weld themselves on to the compound. Above the lead I spread a thin layer of the substance, into which the tubes are afterwards fastened.

Finally, a new layer of plastic substance is laid over the radium preparation, completely covering it and protecting it from dislocation; for safety's sake the edge is welded down on to the applicator by means of a hot iron. This protective layer may often with advantage be extended to the neighbourhood of the apparatus, and will then contribute to the fixation.

In the same way as the lead filters protective plates of the same metal may be applied, in order to prevent the irradiation of the surrounding healthy parts. Here the weight of the lead is of very little account — the case being quite otherwise than in applications by means of sticking-plaster —, for owing to the exact fitting and the wide area of contact against the tumour the applicator can support considerable weights.

It is at once evident that in this way the radium can be both more easily and more exactly applied than with the method recommended by ALBANUS, viz. attaching with sticking-plaster to the applicator. Moreover, as has already been pointed out in the introduction, with copiously

secreting tumours, or in applications upon the mucous membranes, the sticking-plasters are very unreliable.

In different cases all kinds of modifications can naturally be made in the preparation of the applicator. Thus the various parts can be applied in different order, either before or after the application upon the place of treatment. In this very possibility of adaptation the method, of course, presents a great advantage.

If all is correctly carried out, the applicator should fit exactly, should adapt itself well to all the forms taken by the surface of the skin, and should not cause pressure or discomfort in any place. Otherwise the apparatus is either incorrectly applied or has been wrongly prepared. The error may have arisen during the previous manipulations, and may then sometimes be corrected by *careful* heating and renewed application with gentle pressure; otherwise the work must be carried out anew.

The main features of the process here described may be applicable as a scheme more particularly to outward application. Not seldom, however, especially in certain membranous regions, other methods must be used. Thus, the radium tubes may be embedded in the soft plastic substance and be placed in the cavity or crater of the tumour, the thickness of the mass being measured by the eye; where the position or consistency of the tumour does not permit of an impression, an applicator can be prepared according to the results of palpation, etc.; and finally all kinds of combinations of this method can be worked out *in situ* for different cases.

It is evident that the fixing of such contrivances upon the place of treatment is in many, perhaps most, cases considerably facilitated by the plastic substance itself, partly through its extension over a wide surface of the skin, and partly also through the use of the firm points of support to be found in certain places, as described below. Finally, a very good fixation can be obtained by applying the warm compound directly upon the skin, without first rubbing this with grease, since the substance will adhere quite firmly to the surface of the skin.

However, as a rule some outward means of fixing must be used. Here it is both possible and desirable to restrict the use of plasters, since they not seldom cause an irritation in the skin, which should be avoided if possible, and, moreover, are in most cases unnecessary. A firmly applied surgical bandage, the folds of which are carefully made to lie exactly over the right points of application, will, as a rule, be sufficient. In the fixing of the bandage care should be taken that the patient is not incommoded by it: nor need it cover the whole of the apparatus. It is indeed an advantage that it should not do so, for then the substance can less easily become warm and soften. By means of

specially made ridges and elevations in the applicator the bandage can be given better support.

The *cost of the plastic method* of application must be considered as quite trifling. The price of an applicator has been calculated by BERWEN (1917) to be on an average 1—2 shillings while, for example, the mouth-plates prepared by dentists involve an expense of two pounds or more.

Since, however, it has been impossible during the war to use fresh material for every new case, we generally use the substance several times, and this may easily be done, since KERR at least will bear sterilising by boiling without rapidly losing its plasticity.

The applicators used we, therefore, thoroughly clean with brushes and soap and cold water, after which they are laid in warm water, where they soften and can be taken to pieces. The radium tubes with their tinfoil coverings are removed by pulling the cords. The substance is then left to stand in soap and water for 12 hours, after which it is again brushed, washed, and finally wrapped in a compress of gauze and sterilised by boiling for 5 minutes. It is then formed into flat cakes, which are allowed to harden on a glass plate greased with paraffin, and are then cut to the required sizes. Both by this admixture of fat and by the addition of fresh material the plasticity is maintained pretty well, though naturally it is lost in the end.

In this fashion most of the impurities are removed, and bad smells are reduced to a minimum. But of course it is obvious that plastic substance which has been put e. g. to gynecological use must under no circumstances be used in the pharynx or cavity of the mouth.

B. Special Part

In the following I pass on to describe the special use which has been made by us of the plastic method of application in radium treatment of tumours in various parts of the body.

4. The Plastic Method of Application in the Case of Tumours of the Face, Head, and other external Regions of the Body

The great majority of tumours of the face and exterior surface of the head, in consequence of their own form and the usually firm foundation upon which they grow, afford clear and well-defined impressions which facilitate an exact localisation of the radium in the applicator. It is a striking fact that the irregular curved surfaces of the face, which render

Fig. 10. Applicator for perforating nasal cancer.

difficult an application by means of sticking-plaster etc., are, on the contrary, of assistance when the plastic method is used, since the projecting subcutaneous portions of bone and cartilage afford excellent points of support in the fixing of the applicator. Certain tumours ultimately rise so pronouncedly above the outer surface of the skin that the impression which they leave is sufficient to guarantee an exact application. In most cases, however, it is necessary to allow the applicator to extend far out over the surrounding region in order that it may have sufficient support and foundation to be able to bear the weight of the radium, filters, and protective appliances.

For facial tumours, therefore, only fresh and ductile plastic compound is suitable, and this should be carefully modelled over the points of support afforded in the special case. As a general rule I use a secondary filter of a thickness of 4—6 mm., but in treating specially large or deep tumours, which require a very powerful radium preparation, I increase the thickness to 8—10 mm., in order to mitigate the reaction of the skin.

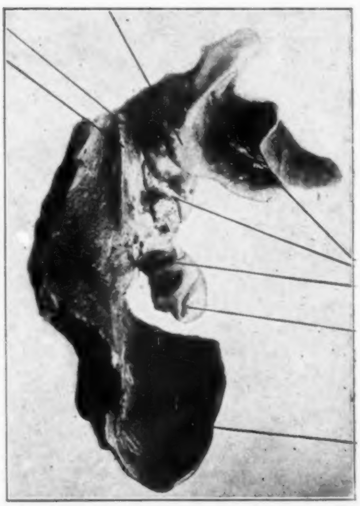


Fig. 11. The same applicator from the inside.

With larger, painful ulcerations it is often best, as Berven has pointed out, to protect the surface of the ulcer and its inflamed neighbourhood by a thin compress of ointment, which is afterwards covered with a thin layer of plastic substance attached by means of bridges or offshoots to the uninjured skin; here the fixation proper is performed by means of plastic substance, stickingplaster, and bandages.

Sometimes it is more convenient first to fix a small applicator over the tumour

itself and to attach the radium to it *in situ*, afterwards applying a greater quantity of plastic substance as a protective covering, and modelling this over any points of support that may be given.

Fig. 12. Tumour of infraorbital region.

For the better demonstration of the various possibilities of the method in the case of external tumours I here add a few examples: —

I. Perforating nasal cancer. A man aged 69 had a cancer which had entirely destroyed the ala of the right nostril and had extended from the nasal bone to the upper fold of the gums, which was filled up by a hard tumour.

I here prepared an applicator in three parts: an upper part, which covered the great wound-cavity in the nose; an inner part, which was introduced into the nasal cavity like a plug; and a lower part, which included the lower lip and reached up to the buccal fold. These parts were welded together *in situ*, and formed an immovable apparatus by means of which 185 mg. of $RaBr_2$, divided into 12 tubes, could be applied (see fig. 10—11). Cured after 3 irradiations.

Fig. 13. Applicator for the above tumour.

The case well shows the power of the plastic method in fixing the radium, producing cross-fire irradiation etc. even with very complicated forms of tumours, while the apparatus all the time remained immovable, though the treatment lasted as long as 20 hours at a stretch.

2. Cutaneous sarcoma of the infraorbital region in a four-year-old girl. A tumour of rapid growth, of the size of a hazelnut, just below the outer corner of the right eye (fig. 12).

Fig. 14.

In this case, on account of the soft consistency and great mobility of the cheek, the applicator, in order that sufficient support might be gained, had to embrace the orbital region, the forehead, the temples, and the nose. The tumour left a very clear impression which admitted of an absolutely exact localisation of the radium. (Fig. 13.) As a protection to the eye-ball a separate leaden plate was introduced into the plastic substance. — Cured after $2^1/_2$ months.

Thus with tumours in the cheek points of support can be obtained against the nose, the orbital margin, the ear, according to the situation of the tumour. The applicator may therefore often be quite large, and for this reason it is sometimes preferable, especially in the case of small tumours, to use sticking-plaster. With these tumours the lower jaw is unsuitable as a point of support, on account of the movements of the mouth.

3. Cancer of the outer ear. A man aged 54, with a hard ulcerated tumour which had penetrated the greater part of the concha and also vegetated at the back surface (fig. 14).

In order to grip the concha firmly and at the same time to furnish a hold to a thick leaden plate which was to protect the sensitive mastoid region from irradiation, a thick ring of plastic substance was first placed around the ear. To this ring there was then fastened over the tumour itself a foundation of the compound 4 mm. thick, upon which the radium and filters were fixed. The whole was finally covered with plastic substance which was moulded down all round on to the bottom plate. (Fig. 15).

In the treatment of the posterior surface of the ear I prepared an impression of this with the ear bent forward (this again being to protect the skin lying behind). The radium was attached to the impression, after which more plastic substance was laid on *in situ* and carried forwards round the concha for the purpose of fixing. —

With tumours in the outer ear or its neighbourhood it is therefore the concha itself that is taken as a point of support for the radium application. With the old method of application by means of sticking-

plaster it was always a delicate matter to fix the radium tubes with their heavy filters in a reliable manner upon the flexible ear. The plastic substance again, after hardening converts the ear into a firm foundation for the radium, and on the other hand can be so fitted into the folds of the ear that an excellent support is afforded for application even on tumours in the neighbourhood of the ear.

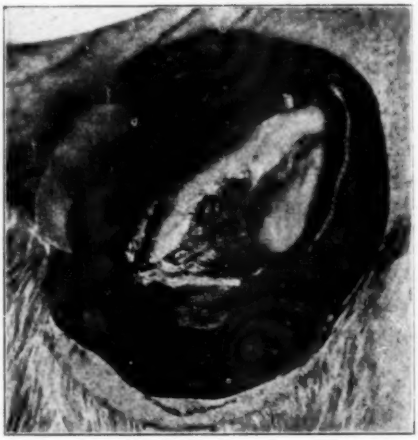


Fig. 15. Applicator for auricular cancer.

With tumours in the *temporal* and *parotid* region. I therefore attach the applicator by means of a semicircular piece of plastic substance placed around the upper part of the auricle, or else by moulding it firmly on to the front side of the ear. A firmly fitting bandage should of course always be applied (fig. 16).

On account of the relatively poor nutritive conditions of the concha it is best to try to bring about complete resorption of its tumours with *one* series of irradiation, using strong doses and a somewhat increased focal distance; otherwise necrosis and relapse may easily set in.

Tumours in *the occipital region* and *the soft parts of the skull* may also with advantage be treated with the aid of the plastic method of application. If the tumour is situated in the forehead, the impression plate should be made rather large and should be carefully modelled over the orbital margins so that a good support may be obtained. In a case of a *gigantic cancerous tumour in the back of the head*, arising from an atheroma, I made out of plastic compound a cap-like cast of the tumour which was supported against the left ear and upon which the radium and its filters were applied.

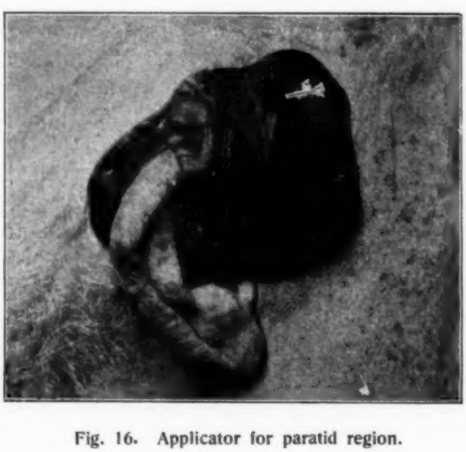


Fig. 16. Applicator for paratid region.

A child 10 weeks old had

Fig. 17. Great angioma of the neck of a child.

on the right side of the neck a partly subcutaneous angioma, twice the size of a hen's egg, which during the course of a year was several times treated with radium by means of the old sticking-plaster method. It was very difficult to attach the radium to the soft loose skin, and for this purpose I was obliged to construct a special filter of brass. It was a great advantage when for this I was able to substitute a collar-shaped applicator of plastic substance, which embraced the upper half of the neck and was fixed in position by a large bandage wound over head and chest. In this manner the preparation could be applied without difficulty, under the guidance of the impression (see figs. 17—18, taken before and after the treatment).

However, in radium therapy there not seldom occur cases to which the method here described is not entirely applicable, e. g. with subcutaneous non-prominent tumours which give no impression, or with flat tumours in the skin, where there are no clearly defined forms and no firm points of support in the vicinity. In such cases I have proceeded in the following way.

After careful palpation of the tumour I mark out its circumference with an aniline pencil. The skin is then greased, and the plastic substance is applied over so wide an area that with the succeeding application of the bandage a sure fixation is afforded. The circumference of the applicator is cut out *in situ* into characteristic form, and is also marked on the skin with the aniline pen-

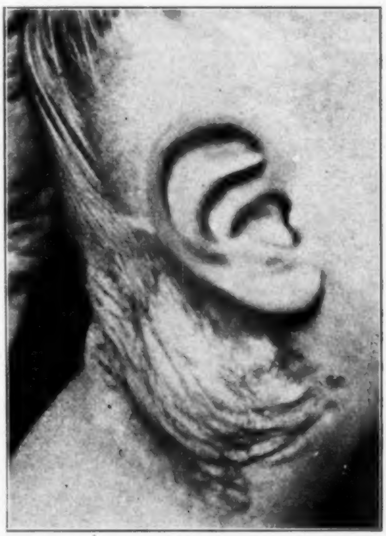


Fig. 18. The above tumour after treatment.

Fig. 19. Marking of limits of tumour and applicator.

cil, for a control of the position. The limits of the tumour are thus marked out on the back of the plate, and this serves as a guide in the attaching of the radium, after which the whole apparatus is once more applied (see figs. 19, 20, 21).

A second method is especially suitable for application *in situ* over smaller areas. Having marked on the skin the limits of the tumour, I apply over this area, without greasing, a smaller quantity of hot plastic substance of a suitable thickness, which therefore adheres firmly to the skin and serves as support and secondary filter for the radium. Over this a greater quantity of soft substance is then applied, this being spread out so that it can give sufficient points of support for the bandage. This applicator must therefore not be taken off before the irradiation is concluded (figs. 22, 23).

Fig. 20. Backside of applicator with impressions of tumour limits.

The plastic substance is therefore of great practical use for radium application in the most widely separated parts of the surface of the skin, since it in the first place admits of an exact localisation of the radium, and also facilitates a better fixing of neighbouring extremities or joints, as e. g. in treatment in the axilla (of gland metastases etc.). Here many modifications can be thought out. In these treatments the

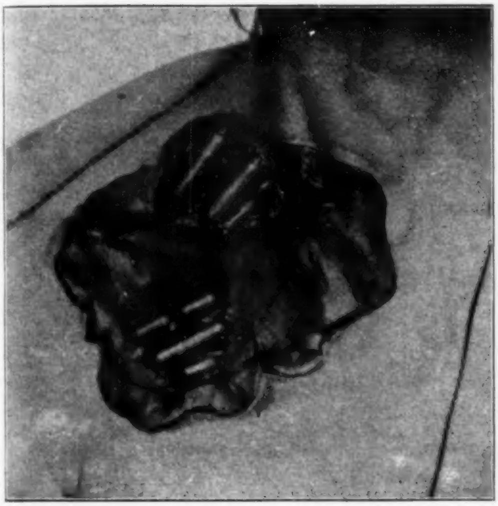


Fig. 21. Applicator complete with radium tubes.

patient should preferably lie motionless in bed; in cases of necessity it may be possible to avoid this by fixing the extremity in question by means of splints or plaster bandages.

In a case of skin metastasis in the axilla after cancer of the breast I proceeded as follows: — The axillary cavity was filled — the patient lying on her back, with abducted arm — with a solid pellet of plastic substance, provided in front with an extension which covered the whole of the skin nodules. The latter producing a clear impression in the substance, an exact placing of the radium was secured. In order to facilitate the application of the offshoot mentioned upon the right spot I had marked its limits on the skin with an aniline pencil. Fixation by means of sticking-plaster and bandages.

Fig. 22. Marking of tumour, application of radium plate.

Another patient had a profound resistence in the left axilla, suspected to be cancer. With abduction of the arm I prepared a saddle-shaped impression-plate of the axilla, about 15 mm. thick, to the lower surface of which were applied two powerful radium tubes and a 2 mm. lead-filter (see fig. 24). Outside the capsules was placed a protective plate of lead 3 mm.

thick, in order to prevent the irradiation of the inside of the arm, and the axilla was then filled up with plastic substance. Fixation as in the preceding case.

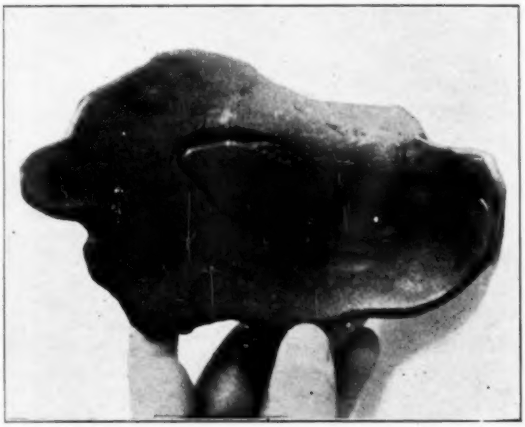


Fig. 23. Backside of applicator with radium plate embedded.

5. The plastic Method of Application in the Case of Tumours of the Eye-lids, Canthi, and Orbita.

In consequence of the small dimensions and great mobility of the eyelids, combined with the sensitiveness of the lids and conjunctiva, and in particular on account of the immediate neighbourhood of the eyeball, the application of radium by the old methods was in these cases always very difficult. Here the experience gained by us with the plastic method of application has proved beyond all doubt the superiority of the method.

As Berven has pointed out, care must always be taken in an application of this nature to ensure sufficient protection for the eyeball both against over-irradiation and against mechanical irritation, and the sensitiveness of the eye will then afford an exellent indicator of the correct position of the radium. It is therefore often preferable to avoid cocainisation, and further — especially in the case of elderly people — not to exert undue pressure upon the ball, so that no increase of the intra-ocular pressure may arise.

With *smaller outward cancers of the lid* it is best to make a mould of the whole neighbourhood of the eye, the plastic compound being well modelled over both the supraorbital margin and also over the root of the nose and the inner *canthus*, so that it may have a sure support against these parts. If the tumour, as is usually the case, gives a clear impression, it will be sufficient to attach the radium preparation (preferably in very small but powerful capsules) and the filter carefully over this. Otherwise it has been found advisable to adopt Berven's device, making a little hollow with a hot iron in the plastic substance in the neighbourhood of the tumour and pressing

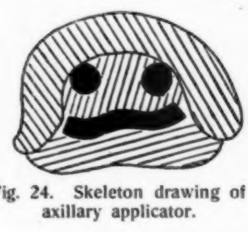


Fig. 24. Skeleton drawing of axillary applicator.

down the radium tubes into this hollow by means of the same plastic material after the attaching of the applicator. It is obvious that here also, as in most other cutaneous regions, the marking out of the place of the tumour by means of an aniline pencil, as described above, may be performed with advantage. In order to protect the ball I generally fix a correspondingly shaped leaden plate 2 mm. thick obliquely in the plastic substance.

Much greater difficulty arises in the application with *deep carcinomata* or those growing in the conjunctiva, where the radium has to be applied in the conjunctival fold itself. The task before us here is on the one hand to ensure an exact and safe attaching of the capsule to the tumour, but on the other hand to avoid mechanical injury or burning of the sensitive cornea by the radium.

Various methods may in this case be recommended. BERVEN's method is to attach the radium to a small hook, the inner end of which rests in the conjunctival fold, and by the aid of which the lid is drawn away from the ball. The outer end is attached by connexion with the ends of a semicircular layer of plastic substance placed around the orbital margins. The application of the hook is facilitated by strips of sticking-plaster which draw down the lower lid and fix the mimic musculature of the face.

I myself have attempted in a few cases to substitute for the hook a small *impression-pellet* made of plastic substance, which contains a radium tube and is fitted with a leaden plate to protect the eyeball. The pad should conform to the shape of the ball, and must not be so large as to come into contact with the cornea. It has a handle by means of which, after application in the conjunctiva, it is fastened down on the applicator placed around the orbita. In the cases in which this method was used no injury was perceived which could be ascribed to the pad. A short preliminary experimental application should perhaps be recommended, in order to obviate the danger of a latent tendency to increasing intraocular pressure.

The best method of application for conjunctival tumours however (except for the cases in which the neoplasm lies very far in a temporal or nasal direction in the canthus, or else on the upper lid) seems to me to be the following. A leaden plate 1 mm. thick has its broader end bent across the upper orbital margin in the shape of a bayonet, and lower down is given a curve in conformity with the convexity of the ball. The lower end is cut square and supports the radium capsule, which is embedded in plastic substance. After cocainisation, to which there is here no objection, the capsule is introduced into the lower conjunctival fold where it is to remain, the eye is closed and the upper end of the leaden plate is supported against the supraorbital

margin. Thus the cornea is covered by the upper lid and protected from damage. The leaden plate is finally enclosed in an applicator of circular shape, attached to the neighbourhood of the orbit. In case of more abundant secretion the eye can be drained by means of a small compress of cotton wool. I have found this method turn out extraordinarily well, and it is now employed by us in the majority of cases.

Finally a few words are to be added on the use of the plastic method in irradiation of the orbita where exenteration has been made on account of a malignant tumour. It was formerly not an easy matter to fix the radium safely in such a copiously secreting cavity, especially with the use of lead filters, which had to be modelled in accordance with the shape of the crater. By the aid of the plastic substance the problem is easily solved. When the cavity has been cleaned out, the plastic substance is simply modelled over its walls to a suitable thickness, and is further extended over the orbital margin. The radium tubes, with or without filters, can then be conveniently fastened on the inside, after which the cavity is filled with plastic substance in order to fix the radium well. A well-applied bandage completely safeguards the application.

To be continued.

Die Intensitätsverteilung der primären γ-Strahlung in der Nähe medizinischer Radiumpräparate

von

Rolf M. Sievert

Inhaltsverzeichnis:

Einleitung

Es scheint, als wäre bis vor kurzem die Intensitätsverteilung der γ-Strahlung in der Nähe von nicht punktförmigen Strahlungsquellen,

wie sie in der Radiumtherapie vorkommen, weder mathematisch noch experimentell untersucht worden. Wahrscheinlich sind auch die vielen, in den Arbeiten über biologische Strahlenwirkungen einander widersprechenden Resultate zum grössten Teil infolge ungenügender Kenntnis der »physikalischen Dosis» entstanden. Letztere steht bekanntlich in engem Zusammenhang mit der Intensitätsverteilung. Zwar findet man hier und da in der medizinischen Literatur Abhandlungen über die Abhängigkeit der Dosis von der »Dispersion» und Absorption, doch mangelt es an für den Praktiker anwendbaren Berechnungen. So haben zum Beispiel DESSAUER (5), HABS (14) und neulich KEHRER (18, 19), MATZDORFF (26) und LAHM (25) auf die Form der Äquiintensitätsflächen bei einfachen und zusammengesetzten Stäbchenpräparaten aufmerksam gemacht. Dieselben Forscher, sowie v. SEUFFERT (35), AMREICH (1) u. a. haben die Intensitäten, die sich in verschiedenen Abständen von einigen Strahlungsquellen ergeben, berechnet. Es sind aber alles dies nur sehr ungenaue Angaben, deren Übereinstimmung mit der Wahrheit nicht konstatiert ist. Auch von rein physikalischer Seite liegen Berechnungen vor, (2, 20, 27, 33, 37) doch lassen sich diese nicht bei medizinischen Anordnungen verwenden.

Es ist bei den in der Medizin zur Verwendung kommenden, radioaktiven Präparaten schon ein grosser Vorteil, dass die primäre, ungefilterte γ-Strahlung hinsichtlich Härtebereich oder, exakter ausgedrückt, hinsichtlich Spektrum immer als konstant angenommen werden kann. Ein Vorteil ist es auch, dass die relative Intensitätsverteilung unabhängig von der Menge des in dem Präparat befindlichen, radioaktiven Stoff, und stets dieselbe ist [1]. Diese Tatsachen machen es zweckmässig, für die gebräuchlichsten Applikatortypen die relative Intensitätsverteilung ein für alle Mal zu bestimmen. Um die erhaltenen Resultate richtig bewerten zu können, ist es wünschenswert, die Sekundärstrahlung der in der Nähe des Präparates vorhandenen Gegenstände, insbesondere die des bestrahlten Objektes, ebenfalls berücksichtigen zu können. Einige nach dieser Richtung hin orientierende Untersuchungen liegen von FRIEDRICH und GLASSER (8) vor. Vor kurzem ist auch eine mathematische Behandlung des Streustrahlenproblems von GLOCKER und KAUPP (12) erschienen.

Zweck der vorliegenden Arbeit ist, einige Berechnungsmethoden für primäre γ-Strahlenintensität anzugeben, und ihre Anwendbarkeit durch Intensitätsmessungen bei kleinen Abständen von den Radiumpräparaten zu prüfen.

---

[1] Dies ist sogar bei den Emanationspräparaten der Fall, da die hier in Frage kommenden γ-Strahlen hauptsächlich von dem kurzlebigen, aktiven Niederschlag emittiert werden.

Theoretischer Teil

§ 1. Die γ-Strahlenintensität als Faktor in der "physikalischen Dosis".

Die »physikalische Dosis», D, die einem unendlich kleinem, in einem Strahlungsfeld befindlichen Volumen, dw, gegeben wird, ist direkt proportional der Bestrahlungszeit, T, der Strahlungsintensität in dw, J, und dem wahren Absorptionskoeffizienten des Gewebes in dw, k. Man hat also:

$$D = T \cdot J \cdot k \cdot dw$$

Für ein endliches Volumen, W, ergibt sich somit:

$$D = \int_W T \cdot J \cdot k \cdot dw$$

Ist die Strahlung aus mehreren Komponenten, K_1, K_2 u. s. w. (vergl. § 2) zusammengesetzt, so kann man statt $J . k$ die Summe $J_{K_1} k_{K_1} + J_{K_2} k_{K_2} + \ldots$ setzen.

Die Intensität, J, ist die Summe zweier Glieder:

$$J = J_I + J_{II}$$

J_I ist durch die Primärstrahlen, J_{II} durch die Sekundärstrahlen hervorgerufen.

Wenn nur γ-Strahlen in Betracht kommen, ist J_I abhängig von:

1) der γ-Aktivität der in der Umgebung von dw sich befindenden, radioaktiven Stoffe. (Totalmenge $= P$ gr. Radiumelement oder P Curie Emanation, vorausgesetzt, dass die Zerfallkette im Gleichgewicht ist.)

2) den Abständen (r) zwischen dw und jedem der kleinen, aktive Materie (Massenelemente $= dp$) enthaltenden Raumelemente (dv).

3) den Absorptionskoeffizienten (μ_1, μ_2 u. s. v. [1]) der zwischen den Strahlungsquellen und dw vorhandenen Stoffe, sowie von deren räumlichen Verteilung.

In demselben Falle ist J_{II} abhängig von der Verteilung und Grösse von J_I in der Umgebung von dw, sowie von der Verteilung, den Absorptionskoeffizienten und der Sekundärstrahlungsfähigkeit der Materie in derselben Umgebung.

---

[1] Totale Absorptionskoeffizienten = »Abschwächungskoeffizienten», Halbwertschicht $= 0.693 \cdot \frac{1}{\mu}$.

Die γ-Strahlung ist also als eine »Volumenstrahlung», nicht als eine »Flächenstrahlung» zu betrachten. Es ist somit selbstverständlich, dass das sogen. Lambertsche Kosinusgesetz hier nicht gelten kann. [1]

§ 2. Die Absorption der primären γ-Strahlen.

Die Absorption der primären γ-Strahlen ist von vielen Forschern untersucht worden. (Ausführliches Literaturverzeichnis s. KOHLRAUSCH (21), Jahrb. d. R. u. E.) Die Resultate divergieren aber sehr, insbesondere infolge der grossen Schwierigkeiten, die Sekundärstrahlung bei den Intensitätsmessungen vollständig zu eliminieren. Es werden deshalb die erhaltenen Werte der Absorptionskoeffizienten immer in grossem Maasse von der Versuchsanordnung abhängig sein. Der einzige Autor, der bisher das Absorptionsproblem der γ-Strahlen nach einigermassen einwandfreier Methode untersucht zu haben scheint, ist wohl FRITZ KOHLRAUSCH (21). Es sollen hier die von ihm gefundenen, für die folgenden Berechnungen von Interesse seienden Werte zusammengestellt werden.

Tabelle 1.

Nach KOHLRAUSCH (21).

Komponente		K_1	K_2	K_3
Relative Anfangsintensität [2]		8	6	1
Absorptionskoeffizient in:	Dichte			
Wasser	1	0.0549	0.0998	—
Kohlenstoff (Graphit)	1.8	0.087	0.153	—
Aluminium	2.7	0.126	0.229	0.57
Zink	7.2	0.322	0.565	1.44
Eisen	7.9	0.356	0.632	3.00
Kupfer	8.9	0.395	0.700	—
Silber	10.5	0.451	0.986	—
Blei	11.3	0.588	1.49	4.6
Quecksilber	13.6	0.621	1.78	—
Gold	19.3	0.901	2.80	—

[1] Wie die α- und β-Strahlungen sich in dieser Beziehung verhalten, ist von RUTHERFORD (31), GREINACHER (13), SCHMIDT (32) u. a. behandelt worden.

[2] Die relative Intensität $\frac{K_3}{K_1 + K_2} = 7.15\,\%$ stimmt sehr gut mit der von SZMIDT (36) beobachteten $\frac{45}{639} = 7.10\,\%$ überein.

Nach KOHLRAUSCH besteht die γ-Strahlung des Radiums (+ Zerfallprodukten) im Wesentlichen aus drei Strahlungskomponenten, deren Intensität[1] und Härte (Wellenlänge) verschieden sind. Er bezeichnet sie mit K_1, K_2 und K_3. Die beiden härteren, K_1 und K_2, stammen wahrscheinlich von *RaC*, die dritte, K_3, die verhältnismässig weich ist, von *RaB*. Wie also schon in der Einleitung bemerkt wurde, so werden die hier in Betracht kommenden γ-Strahlen von dem aktiven Niederschlag ausgesandt.

Tabelle 1 gibt die relative Intensität und die Absorptionskoeffizienten, μ_{K_i}, der verschiedenen Strahlungskomponenten in einigen Stoffen an.

Aus diesen Zahlen lässt sich unter Annahme eines exponentiellen Absorptionsgesetzes die relative Intensität nach Durchgang durch eine absorbierende Schicht für jede der drei Komponenten berechnen. In Tabelle 2 sind einige solche Werte angeführt. Die Prozentzahlen zeigen die Zusammensetzung der durch die verschiedenen Schichten durchgedrungenen Strahlung. Als Einheit ist die Anfangsintensität von K_3 angenommen.

Tabelle 2.

Komponente	K_1	K_2	K_3
Anfangsintensität	8 53 %	6 40 %	1 7 %
Intensität nach Durchgang durch:			
1 mm Blei	7.6 56 %	5.2 39 %	0.63 5 %
2 mm »	7.2 59.5 %	4.5 37 %	0.40 3.5 %
5 mm »	6.1 67 %	2.9 32 %	0.1 1 %

Die »physikalische Dosis» ist, wie in § 1 erwähnt, direkt proportional dem Absorptionskoeffizienten, k, im Gewebe. Dies gilt natürlich für jede einzelne Komponente. Wenn man die im Vergleich zum Wasser etwas grössere Dichte des Gewebes berücksichtigt, kann man die drei Koeffizienten des Gewebes, k_{K_1}, k_{K_2} und k_{K_3} gleich 0.06, 0.11 und 0.25 setzen. Es ergeben sich dann die Werte der Tabelle 3, die den auf jede Komponente kommenden Teil der Dosis nach Durchgang durch 1, 2 und 5 mm Blei zeigt.

[1] Unter Intensität ist die Ionisierungsfähigkeit in der Luft verstanden.

Tabelle 3.

Komponente	K_1	K_2	K_3
Anfangsdosen	0.48 34 %	0.66 48 %	0.25 18 %
Dosen nach Durchgang durch:			
1 mm Blei	0.46 38 %	0.57 48 %	0.16 14 %
2 mm »	0.43 42 %	0.50 48 %	0.10 10 %
5 mm »	0.37 51 %	0.32 45 %	0.03 4 %

Es ist somit nach Tabelle 3 einleuchtend, dass auch die dritte Strahlungskomponente, wenigstens bei geringer Filterung, für die Dosis eine nicht unbedeutende Rolle spielen kann.

§ 3. Einheit der γ-Strahlenintensität.

Als Maass der Intensität ist hier durchweg die Fähigkeit der Strahlen, in Luft Ionen zu erzeugen, angenommen.

Eine für medizinische Zwecke praktische Einheit für γ-Strahlenintensität ist bisher noch nicht festgesetzt worden. MATZDORFF (26) hat eine solche vorgeschlagen, die hier in ein wenig abgeänderter Form benutzt werden soll.

Er sagt: »Die Einheit der Intensität ist vorhanden in einem Punkte, der 1 cm weit vom Mittelpunkte eines mit dem Einheitsfilter umgebenen, kugelförmigen Radiumpräparates von 1 mgr Radiumelement entfernt liegt, wenn zwischen dem Filter und dem Punkte ein, γ-Strahlen nicht absorbierendes Medium liegt. Wir wollen sie 'Einheitsmilligramm-Intensität' (*EmgJ*) nennen.»

Als Einheitsfilter bezeichnet er das von KEETMANN und MEYER und von KRÖNIG und FRIEDRICH (24) angegebene, aus 1.5 mm Messing und 5 mm Celluloid bestehende Filter.

Es wird aber, wenn man eine kugelförmige Strahlungsquelle ohne Angabe des Kugelradius annimmt, diese Einheit nicht eindeutig festgelegt. [Vergl. THIRRING (37), v. SCHWEIDLER (33)]. Auch ist wohl das Einheitsfilter entbehrlich.

Die in der vorliegenden Arbeit benutzten Einheiten ergeben sich aus folgenden Definitionen:

Als »γ-Strahlung» wird nur die harte Strahlung von *RaB* und *RaC* bezeichnet, also die gemäss § 2 aus K_1, K_2 und K_3 bestehende.

Als Einheit der γ-Strahlung wird die Intensität der »γ-Strahlung» ge-

wählt, die sich im Vakuum[1] aus einem Gramm Radiumelement, das im Gleichgewicht mit seinen Zerfallprodukten (eine Curie Emanation) ist, bei einem Centimeter Abstand ergibt. Vorausgesetzt ist dabei, dass alle Teile der Strahlungsquelle gleich weit entfernt sind. Diese Intensität soll hier eine »Curie-Strahlung» (*CS*) genannt werden.

Als praktische Einheit ist es wohl am zweckmässigsten das Tausendstel von dieser, also eine »Millicurie-Strahlung» (*MCS*) anzuwenden.

Man hat demnach in den folgenden Berechnungen immer als Längeneinheit den Centimeter und als Masseneinheit oder Aktivitätseinheit das Gramm und das Milligramm bezw. die Curie und die Millicurie zu benutzen.

Die Zahl der bei 1 *CS* Intensität in Luft bei Atmosphärendruck erzeugten Ionen ist von EVE (6, 7), MOSELEY und ROBINSON (29) u. a. bestimmt worden.

§ 4. Berechnung der Intensität der primären γ-Strahlen.

Setzt man:

$(J_l)_Q$ = totale Intensität im Punkte Q,

N = Anzahl der Strahlungskomponenten (K_1, K_2 ... K_N),

n = Index der Werte, die zu den n-ten der N Strahlungskomponenten (Spektrallinien) gehören,

u_n = Intensität der Komponente K_n, ehe die Absorption stattgefunden hat, in Prozent der gesamten Intensität der N Komponenten,

P = Totalmenge der radioaktiven Materie (vergl. § 1),

dp = Teilelement, dp mgr Radiumelement oder dp Millicurie Emanation enthaltend (vergl. § 1),

r_Q = Abstand zwischen dp und Q (je nach der Lage von dp),

e = Basis der natürlichen Logarithmen,

$\sum_{l=1}^{m} \mu_{nl} d_l(\varphi) = \mu_{n1} d_1(\varphi) + \mu_{n2} d_2(\varphi) + \ldots + \mu_{nm} d_n(\varphi)$

= der in einer gegebenen Richtung, φ, für K_n erhaltenen Summe von Absorptionskoeffizienten (μ_{n1}, $\mu_{n2} \ldots \mu_{nm}$), multipliziert mit den Schichtdicken [$d_1(\varphi)$, $d_2(\varphi) \ldots d_m(\varphi)$] der durchstrahlten Stoffe (μ_{ni} ist also der Absorptionskoeffizient der i-ten von den m Schichten für die Komponente K_n),

so ergibt sich, unter der Voraussetzung, dass die Intensität bei punktförmiger Strahlungsquelle mit dem Quadrat der Entfernung abnimmt, und unter Berücksichtigung eines exponentiellen Absorptionsgesetzes:

[1] Natürlich wird in der Praxis die in Luft gemessene Intensität genügen. Der Absorptionskoeffizient der Luft soll nach CHADWICK (3), HESS (15) u. a. nur 0.00004—0.00006 betragen.

$$(J_l)_Q = \sum_{n=1}^{N} \frac{u_n}{100} \int_P \frac{1}{r_Q^2} \cdot e^{-\sum_{i=1}^{m} \mu_{ni} d_i(\varphi)} \, . \, dp.$$

Ist der Gehalt an γ-strahlender Materie in jedem gleichen dv (vergl. § 1) derselbe, und wird das gesamte Volumen mit V bezeichnet, so kann man auch

$$(J_l)_Q = \sum_{n=1}^{N} \frac{u_n}{100} \cdot \frac{P}{V} \cdot \int_V \frac{1}{r_Q^2} \, e^{-\sum_{i=1}^{m} \mu_{ni} d_i(\varphi)} \, . \, dv$$

setzen.

Es soll hier die Berechnung des Wertes

$$F_n = \frac{P}{V} \int_V \frac{1}{r^2} e^{-\sum_{i=1}^{m} \mu_{ni} d_i(\varphi)} \, . \, dv$$

für einige ideale Fälle durchgeführt werden.

Im allgemeinen sind die erhaltenen Integralen unlösbar. Um das Integral wenigstens approximativ berechnen zu können, ist es deshalb oft zweckmässig, $e^{-\Sigma \mu d(\varphi)}$ in einer Reihe zu entwickeln. Man erhält dann

$$F = \frac{P}{V} \int_V \frac{1}{r^2} \left[1 - \frac{\Sigma \mu d(\varphi)}{1!} + \frac{\overline{\Sigma \mu d(\varphi)}^2}{2!} \dots \right] dv.$$

Im Allgemeinen konvergieren die so erhaltenen Reihen ziemlich rasch, wenigstens bei $\Sigma \mu d < 1$.

$\frac{P}{V}$ ist als »Volumendichte» der aktiven Materie zu betrachten. Wenn der strahlende Körper als flächen- oder linienförmig bezeichnet werden kann, hat man statt dieser die »Flächen»- bezw. die »Liniendichte» einzusetzen. Dabei bedeutet dv das Flächen- bezw. Linienelement.

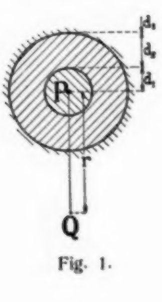


Fig. 1.

In den folgende Figuren ist Q immer der Punkt, dessen F-Wert bestimmt werden soll. Σd ist immer $\leq a$.

A. *Strahlungsquelle:* Punkt.

1) *Absorbierende Materie:* konzentrische, sphärische, homogene Schichten. (Fig. 1).

$$F = P \, . \, \frac{1}{r^2} \, . \, e^{-\Sigma \mu d} \quad \dots (A\ 1).$$

2) *Absorbierende Materie:* ebene, homogene Schichten. (Fig. 2.)

$$F = P \cdot \frac{(\cos\varphi)^2}{a^2} \cdot e^{-\frac{\Sigma\mu d}{\cos\varphi}} =$$

$$= P \cdot \frac{1}{a^2 + b^2} \cdot e^{-\Sigma\mu d \cdot \frac{\sqrt{a^2+b^2}}{a}} \ldots (A\ 2).$$

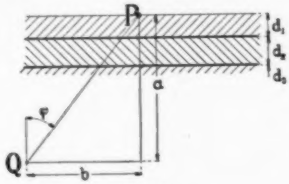


Fig. 2.

Spezialfall zu (A 1) und (A 2):

$$\Sigma\mu d = 0 \text{ (also keine Absorption) gibt } F = P \cdot \frac{1}{r^2}.$$

B. *Strahlungsquelle:* gerade Linie.

1) *Absorbierende Materie:* unendlich lange, konzentrische, cylindrische, homogene Schichten. (Fig. 3.)

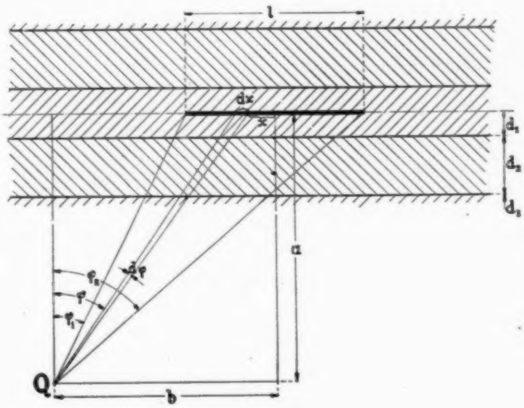


Fig 3.

$$F = \frac{P}{l} \int_{-\frac{l}{2}}^{+\frac{l}{2}} \frac{\cos^2\varphi}{a^2} \cdot e^{-\frac{\Sigma\mu d}{\cos\varphi}} \cdot dx$$

es ist aber $\frac{b+x}{a} = tg\,\varphi$ und $dx = \frac{a}{\cos^2\varphi} d\varphi$, also

$$F = \frac{P}{l \cdot a} \int_{\varphi_1}^{\varphi_2} e^{-\frac{\Sigma\mu d}{\cos\varphi}} \cdot d\varphi = \frac{P}{l \cdot a} \cdot \left[\mathfrak{F}(\varphi_2) - \mathfrak{F}(\varphi_1)\right] \ldots (B\ 1).$$

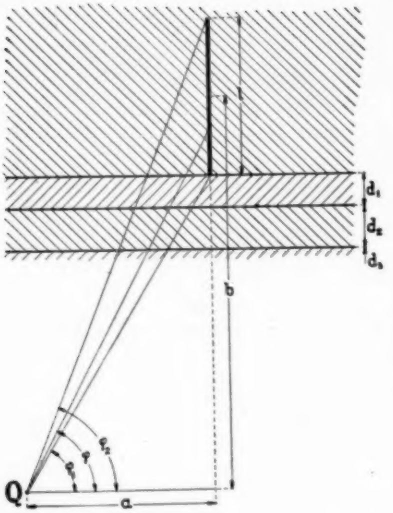


Fig. 4.

In Tafel III sind einige Werte von $\int_0^{\varphi} e^{-\frac{\Sigma \mu d}{\cos \varphi}} \cdot d\varphi = \mathfrak{F}(\varphi)$ bei verschiedenen $\Sigma \mu d$ für jeden 5-ten Grad wiedergegeben.

2) *Absorbierende Materie:* die ganze Linie sei in homogene Materie mit dem Absorptionskoeffizienten ν eingebettet. Rechtwinklig gegen die Linie seien von deren Endpunkten ab unendlich ausgedehnte, ebene, homogene Schichten angenommen.

a) $a > 0$. (Fig. 4.)

In ähnlicher Weise wie in (B 1) ergibt sich:

$$F = \frac{P}{l \cdot a} \int_{\varphi_1}^{\varphi_2} e^{\frac{\nu\left(b - \frac{l}{2}\right) - \Sigma \mu d - \nu \cdot tg\, \varphi}{\sin \varphi}} \cdot d\varphi \ \ldots \ \text{(B 2 a).}$$

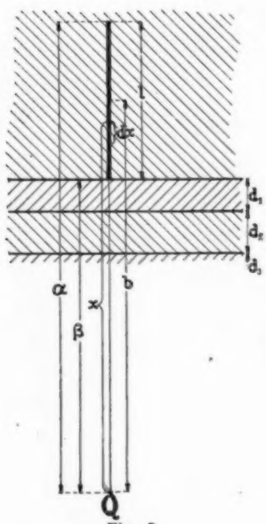


Fig. 5.

Die Auswertung dieses Integrals geschieht wohl am einfachsten graphisch.

Spezialfall zu (B 1) und (B 2 a):

$$\Sigma \mu d = 0, \ \nu = 0, \ \text{also}$$

$$F = \frac{P}{l \cdot a}(\varphi_2 - \varphi_1) \ \text{oder}$$

$$F = \frac{P}{l \cdot a}\left(arc\ tg \frac{b + \frac{l}{2}}{a} - arc\ tg \frac{b - \frac{l}{2}}{a}\right) \ldots \text{(S B).}$$

b) $a = 0$. ν ist der Absorptionskoeffizient der Linie selbst. (Fig. 5.)

Nach der Figur erhält man:

$$F = \frac{P}{l} \int_{b - \frac{l}{2}}^{b + \frac{l}{2}} \frac{1}{x^2} \cdot e^{-\nu\left[x - \left(b - \frac{l}{2}\right)\right] - \Sigma \mu d} \cdot dx.$$

Setzt man $b + \frac{l}{2} = \alpha$ und $b - \frac{l}{2} = \beta$ so ergibt sich:

$$F = \frac{P}{l} \cdot e^{\nu\beta - \Sigma\mu d} \cdot \nu \cdot \left[\mathfrak{E}(\nu\beta) - \mathfrak{E}(\nu\alpha)\right]; \ldots \quad (\mathrm{B\,2\,b})$$

wobei $\mathfrak{E}(x) = \int\limits_x^\infty \frac{1}{x^2} e^{-x}\,dx.$

Numerische Werte dieses Integrals sind berechnet von Miller und Rosebrugh (28). (S. Tafel IV in vorliegender Arbeit.)

Spezialfälle zu (B 2 b):

$$\nu = 0 \text{ gibt } F = P \cdot \frac{1}{\alpha\beta} \cdot e^{-\Sigma\mu d}. \quad \ldots \quad (\mathrm{S\,B_1}).$$

$$\nu = 0 \text{ und } \Sigma\mu d = 0 \text{ gibt } F = P \cdot \frac{1}{\alpha\beta}. \quad \ldots \quad (\mathrm{S\,B_2}).$$

C. *Strahlungsquelle:* Kreisperipherie.

Absorbierende Materie: unendliche, ebene, homogene Schichten, parallel mit der Ebene des Kreises. (Fig. 6.)

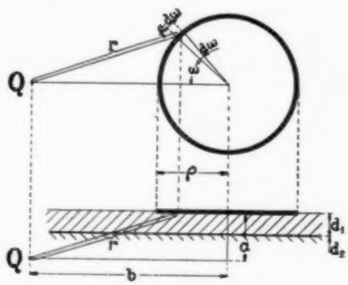


Fig. 6.

Nach der Figur erhält man:

$$F = \frac{P}{2\pi\varrho} \cdot 2 \int\limits_0^{\nu\pi} \frac{1}{r^2} \cdot e^{-\Sigma\mu d \cdot \frac{r}{a}} \cdot ds$$

es ist aber $r^2 = a^2 + b^2 + \varrho^2 - 2\varrho \cdot b \cos\omega$ und $ds = \varrho d\omega$, folglich:

$$F = \frac{P}{\pi} \int\limits_0^{\pi} \frac{1}{a^2 + b^2 + \varrho^2 - 2\varrho b \cos\omega} \cdot e^{-\Sigma\mu d \cdot \frac{\sqrt{a^2+b^2+\varrho^2-2\varrho b\cos\omega}}{a}} \cdot d\omega.$$

Nach Reihenentwicklung und Integrieren ergibt sich:

$$F = P\left\{\frac{1}{\sqrt{(a^2+b^2+\varrho^2)^2 - 4b^2\varrho^2}} - \right.$$

$$- \frac{\Sigma\mu d}{a}\left[\frac{1}{\sqrt{a^2+b^2+\varrho^2}} + \frac{3}{16} \cdot \frac{2\varrho b}{\sqrt{(a^2+b^2+\varrho^2)^5}} + \ldots\right] +$$

$$\left. + \frac{1}{2}\left[\frac{\Sigma\mu d}{a}\right]^2 \ldots\right\} \ldots \quad (\mathrm{C}).$$

Spezialfälle zu (C):

$$b = 0 \text{ gibt } F = \frac{P}{a^2 + \varrho^2} \cdot e^{-\Sigma\mu d \cdot \frac{\sqrt{a^2+b^2}}{a}} \quad \ldots \text{(SC)}.$$

$$\Sigma\mu d = 0 \text{ gibt } F = P \cdot \frac{1}{\sqrt{(a^2 + b^2 + \varrho^2) - 4\, b^2 \varrho^2}} \ldots \text{(SC}_1\text{)}.$$

$$\Sigma\mu d = 0 \text{ und } a = 0 \text{ gibt } F = P \cdot \frac{1}{b^2 - \varrho^2} \cdot \ldots \text{(SC}_2\text{)}.$$

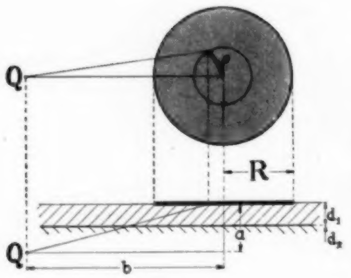


Fig. 7.

D. *Strahlungsquelle:* kreisrunde Scheibe.

Absorbierende Materie: mit der Scheibe parallele, unendlich ausgedehnte, homogene Schichten. (Fig. 7.)

Man kann die Scheibe in konzentrische Kreisringe mit den Radien ϱ und der Breite $d\varrho$ zerlegen. Durch Summieren dieser Elemente erhält man

$$F = \frac{P}{\pi} \int_0^R \int_0^\pi \frac{1}{a^2 + b^2 + \varrho^2 - 2\, \varrho\, b \cos\omega} \cdot e^{-\Sigma\mu d \cdot \frac{\sqrt{a^2+b^2+\varrho^2-2\,\varrho\, b\cos\omega}}{a}} \cdot d\omega \cdot d\varrho$$

oder mit Hilfe der Formel approximativ:

$$F = \frac{P}{\pi R^2} \int_0^R \left\{ \frac{1}{\sqrt{(a^2 + b^2 + \varrho^2)^2 - 4\, b^2 \varrho^2}} - \frac{\Sigma\mu d}{a} \cdot \frac{1}{\sqrt{a^2 + b^2 + \varrho^2}} + \right.$$

$$\left. + \frac{1}{2} \left[\frac{\Sigma\mu d}{a}\right]^2 \right\} 2\, \pi\varrho \cdot d\varrho\,.$$

Nach Integrieren ergibt sich somit:

$$F = P \left\{ \frac{1}{R^2}\, {}^e\log \frac{R^2 + a^2 - b^2 + \sqrt{(R^2 + a^2 - b^2)^2 + 4\, a^2 b^2}}{2\, a^2} - \right.$$

$$\left. - 2\, \frac{\Sigma\mu d}{a} \cdot \frac{\sqrt{a^2 + b^2 + R^2} - \sqrt{a^2 + b^2}}{R^2} + \frac{1}{2} \left[\frac{\Sigma\mu d}{a^2}\right]^2 \right\} \ldots \text{(D)}.$$

Spezialfälle zu (D):

$\Sigma \mu d = 0$ gibt

$$F = \frac{P}{R^2} {}^e\log \frac{R^2 + a^2 - b^2 + \sqrt{(R^2 + a^2 - b^2)^2 + 4\, a^2\, b^2}}{2\, a^2} \quad \ldots \text{(SD}_1\text{)}.$$

$$\Sigma \mu d = 0,\; a = 0 \text{ gibt } F = \frac{P}{R^2} {}^e\log \frac{b^2}{b^2 - R^2} \quad \ldots \text{(SD}_2\text{)}.$$

$$\Sigma \mu d = 0,\; b = 0 \text{ gibt } F = \frac{P}{R^2} {}^e\log \frac{R^2 + a^2}{a^2}. \quad \ldots \text{(SD}_3\text{)}.$$

Im Falle von $b = 0$ kann man, auch wenn $\Sigma \mu d$ nicht gleich 0 ist, das Integral ziemlich bequem berechnen. (Fig. 8.)

Man hat nämlich dann:

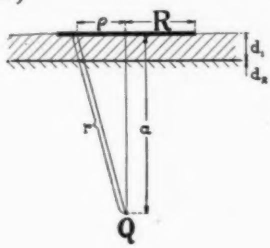


Fig. 8.

$$F = \frac{P}{\pi R^2} \int_0^R \frac{2 \pi \varrho}{r^2} \cdot e^{-\Sigma \mu d \cdot \frac{r}{a}} \cdot d\varrho$$

aber $\varrho^2 + a^2 = r^2$ und $\varrho\, d\varrho = r dr$.

Es ergibt sich also:

$$F = \frac{2\,P}{R^2} \int_a^{\sqrt{a^2+R^2}} \frac{1}{r} \cdot e^{-\Sigma \mu d \cdot \frac{r}{a}} . dr = \frac{2\,P}{R^2} \left\{ Ei \left[-\frac{\Sigma \mu d}{a} \sqrt{a^2 + R^2} \right] - \right.$$

$$\left. - Ei \left[-\Sigma \mu d \right] \right\} \quad \ldots\ldots \text{(SD)}.$$

wobei

$$- Ei(-x) = \int_x^\infty \frac{e^{-x}}{x} dx.$$

Numerische Werte des sogenannten »Exponentialintegrals» $-Ei(-x)$ sind in Tafel V zusammengestellt.

§ 5. Anwendung der in § 3 abgeleiteten Formeln auf einige, in der Radiumtherapie vorkommende Fälle.

1. *Stabförmige Präparate.*

a) Nur *ein* Präparat. Gegeben sei ein cylindriches Präparat von der Form der Figur 9. H—H soll die Haut, S—S ein Sekundärfilter sein.

Als Bezeichnungen sind die schon vorher benutzten genommen. Die beiden Winkel φ_1 und φ_2 seien beide positiv, wenn an derselben Seite der Normale QR liegend, bezw. der grössere positiv und der kleinere negativ, wenn an verschiedenen Seiten liegend. Ferner sei der Abstand zwischen Punkt Q, für welchen die Intensität bestimmt werden soll, und der Cylinderachse im Vergleich zum Diameter des mit radioaktiver Materie gefüllten[1] Hohlraumes, verhältnismässig gross (wenigstens 4—5 Mal so gross wie jener[2]). Es lässt sich dann die Intensität in Q, vorausgesetzt Q befindet sich in dem von den konischen Flächen K—K und K¹—K¹ begrenztem, in Figur 9 mit I bezeichnetem Gebiet, mit Hilfe von der Formel (B 1) berechnen. Es ist also:

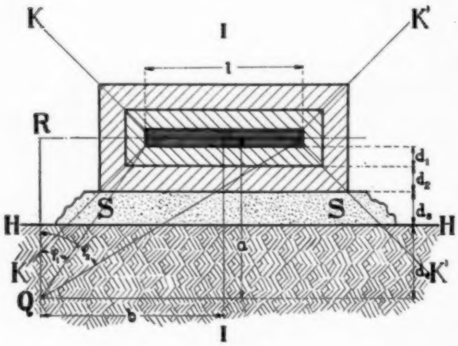


Fig. 9.

$$J_I = \frac{P}{l} \cdot \frac{1}{a} \left\{ \frac{53}{100} \left[\mathfrak{F}(\varphi_2)_{K_1} - \mathfrak{F}(\varphi_1)_{K_1} \right] + \frac{40}{100} \left[\mathfrak{F}(\varphi_2)_{K_2} - \mathfrak{F}(\varphi_1)_{K_2} \right] + \right.$$

$$\left. + \frac{7}{100} \left[\mathfrak{F}(\varphi_2)_{K_3} - \mathfrak{F}(\varphi_1)_{K_3} \right] \right\}; \quad \ldots (1)$$

wobei

$$\mathfrak{F}(\pm \varphi)_K = \pm \int_0^{\varphi} e^{\frac{-(\Sigma \mu d)_K}{\cos \varphi}} \, . \, d\varphi.$$

Tafel III zeigt die Werte der Funktion $\mathfrak{F}(\varphi)$ für verschiedene φ und $\Sigma \mu d$. In Figur 9 hat man zum Beispiel:

$$(\Sigma \mu d)_K = (\mu_1 d_1 + \mu_2 d_2 + \mu_s d_s + \mu_e d_e)_K$$

wobei μ_1, μ_2, μ_s und μ_e die Absorptionskoeffizienten der betreffenden Strahlungskomponenten in den Schichten 1, 2, s und e bedeuten. Die Winkel φ_1 und φ_2 sind durch

[1] Man achte darauf, dass der Hohlraum sehr oft nicht ganz ausgefüllt ist. Dabei ist natürlich die Intensitätsverteilung je nach den Lagen des Präparates eine verschiedene.

[2] Für den extremen Fall, dass der radioaktive Stoff an der Cylinderwand haftet (Emanationspräparate!), kann man die Abweichungen mit Hilfe von der Formel (C) wenigstens schätzungsweise bewerten.

$$tg\,\varphi_1 = \frac{b - \frac{l}{2}}{a}, \qquad tg\,\varphi_2 = \frac{b + \frac{l}{2}}{a}$$

bestimmt, weshalb auch diese Werte in die Tafel eingetragen worden sind. Aus Tafel I ergeben sich die μ-Werte der drei Komponenten. Die mit ·) bezeichneten Zahlen sind durch Interpolation bezw. Extrapolation aus den KOHLRAUSCH'schen Werten erhalten.

Die ganze Intensitätsberechnung lässt sich, wie folgt, schematisch aufstellen:

$P = 21$ mgr, $l = 3$ cm, $a = 2$ cm, $b = 0.5$ cm.

	$\mu_{K_1}d$	$\mu_{K_2}d$	$\mu_{K_3}d$
$d_1 = 0.1$ cm *Ag*:	0.045	0.099	0.40
$d_2 = 0.2$ cm *Pb*:	0.106	0.298	0.92
$d_s = 0.2$ cm (Dichte = 2):	0.020	0.040	0.10
$d_e = 1.5$ cm (Dichte = 1.1):	0.090	0.160	0.40
$\Sigma\mu d$:	0.26	0.60	1.8

$$tg\,\varphi_1 = \frac{0.5 - 1.5}{2} = -0.5 \text{ und } tg\,\varphi_2 = \frac{0.5 + 1.5}{2} = 1.0.$$

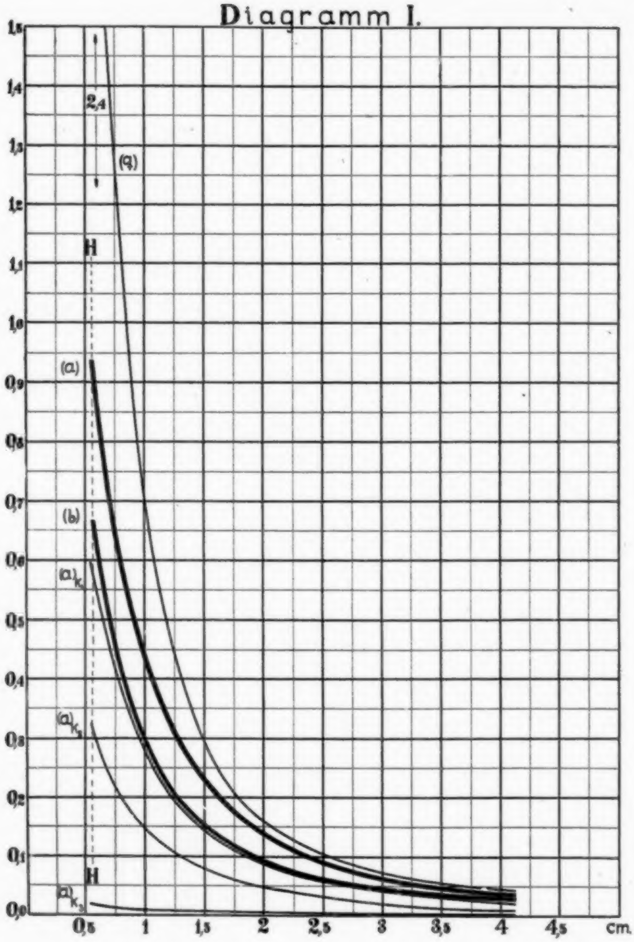
	K_1	K_2	K_3
$\mathfrak{F}(\varphi_2)$:	0.589	0.401	0.110
$\mathfrak{F}(\varphi_1)$:	−0.354	−0.249	−0.074
$\mathfrak{F}(\varphi_2) - \mathfrak{F}(\varphi_1)$:	0.948	0.650	0.184
$(J_l)_K = \frac{21}{3} \cdot \frac{1}{2} \cdot \frac{a}{100}\left[\mathfrak{F}(\varphi_2) - \mathfrak{F}(\varphi_1)\right]$:	1.75	0.91	0.045

$$J_l = 2.7 \; MCS.$$

In Diagramm I zeigt die Kurve (a) den Intensitätsabfall auf der Mittelpunktsnormale eines 3 cm langen, stabförmigen Präparates bei der in obigem Beispiel angegebenen Filterung. $(a)_{K_1}$, $(a)_{K_2}$ und $(a)_{K_3}$ sind die den einzelnen Komponenten entsprechenden Kurven. Zwecks Vergleich ist die für eine punktförmige Strahlungsquelle mit demselber Filter berechnete Kurve (q) daneben gezeichnet. Um aus den Ordinaten der Kurven die Intensitäten in *MCS* zu ermitteln, hat man nur mit dem Radium oder Emanationsgehalt, *P* Milligramm bezw. Millicurie, zu multiplizieren.

Nach den anderen Richtungen hin, also an den Enden des Präparates, ist die Intensitätsberechnung eine viel schwierigere. Der Diameter des Hohlraumes und die Konstruktion des Filters haben hier einen viel grösseren Einfluss auf die Verteilung der Intensität, als in dem oben behandelten Falle. Ist der Hohlraum sehr eng, und der Filter aus nur

Diagramm I.



einer Art Material, kann man mit Hilfe des Integrals (B 2 a) die Intensität in der Zone III (s. Fig. 10) berechnen. Man hat dann $\nu = \mu_K$ und $\Sigma \mu d = \mu_K \cdot d$ zu setzen, wodurch sich für jede Strahlungskomponente

$$(J_l)_K = \frac{P}{l \cdot a} \cdot \frac{u_K}{100} \int_{\varphi_1}^{\varphi_2} e^{-\mu_K \cdot \frac{b - \frac{l}{2} d - a \, tg \, \varphi}{\sin \varphi}} \cdot d\varphi \quad \ldots . (2)$$

ergibt. Das Integral ist graphisch auszuwerten.

In der Zone II wird die Berechnung zweckmässig in zwei Teile zerlegt. Für den Punkt Q (s. Fig. 10) wird zum Beispiel die Strahlung des Teils c_1 nach Formel (1), die des Teils c_2 nach Formel (2) bestimmt.

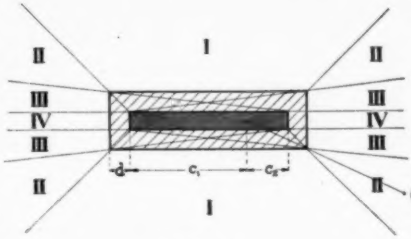


Fig. 10.

Schliesslich ist die Intensität in der Richtung IV nach Formel (B 2 b) zu berechnen. Man hat hier ν als den Absorptionskoeffizienten der radioaktiven Materie selbst zu betrachten. Setzt man

$$F(\alpha,\beta)_K = \nu \cdot e^{\nu\beta - \Sigma\mu d} \cdot \left(\int_{\nu\beta}^{\infty} \frac{1}{x^2} e^{-x} \cdot dx - \int_{\nu\alpha}^{\infty} \frac{1}{x^2} e^{-x} \cdot dx \right)$$

so wird in Analogie mit der Formel (1):

$$J_l = \frac{P}{l} \left[\frac{53}{100} F(\alpha,\beta)_{K_1} + \frac{40}{100} F(\alpha,\beta)_{K_2} + \frac{7}{100} F(\alpha,\beta)_{K_3} \right] \ldots (3).$$

Einige numerische Werte der Funktion $\mathfrak{E}(x) = \int_x^{\infty} \frac{1}{x^2} e^{-x} \, dx$ befinden sich in Tafel IV.

Die Kurve (b) im Diagramm I zeigt bei demselben Präparat und Filter wie im Beispiel auf Seite 103, den Intensitätsabfall in der Richtung IV, wobei vorausgesetzt ist, dass die Absorptionskoeffizienten der Radiumsalze = 0.2, 1 und 8 seien (vergl. Anmerkung, Seite 110). Der Abstand a ist hier von einem Punkte aus gerechnet, der der Kurve in Bezug auf die Oberfläche des Präparates dieselbe Lage gibt, wie Kurven (a) und (q). Es ist somit die Intensität auf die Haut in allen drei Fällen bei der Abszisse »H« zu suchen. Da bei den Absorptionskoeffizienten der Radiumsalze aber mit einem bedeutenden Fehler, der sogar über 100 % betragen kann, gerechnet werden muss, sind die nach (3) berechneten Intensitätswerte allerdings sehr unsicher.

b) *Mehrere* Präparate. Sind mehrere Präparate zu einem Applikator zusammengefügt, wie es ja in der Radiumtherapie am häufigsten vorkommt, so hat man die Intensität durch Summieren der einzelnen von jedem Präparat hervorgerufenen Intensitäten zu bestimmen.

Hier soll nur der Fall herausgegriffen werden, dass die Präparate in einem Kreise liegen. Ist dabei die Abweichung von einem regelrechten Kreise nicht allzu gross, so kann die Berechnung nach Formel (C) durchgeführt werden. Unter solchen Umständen dürfen aber die cylindrischen Filter der einzelnen Präparate nur sehr dünn sein. Ist die Applikation etwa wie in Fig. 11 ausgeführt, erhält man für jede Strahlungskomponente:

$$(J_l)_K = P \cdot \frac{u_K}{100} \cdot e^{-\Sigma \mu_K d} \cdot \left\{ \frac{1}{\sqrt{(a^2 + b^2 + \varrho^2)^2 - 4 b^2 \varrho^2}} - \right.$$

$$\left. - \frac{\mu_s d_s + \mu_e d_e}{a} \cdot \frac{1}{\sqrt{a^2 + b^2 + \varrho^2}} + \frac{1}{2} \left[\frac{\mu_s d_s + \mu_e d_e}{a} \right]^2 \right\}_K \quad \ldots . (4).$$

Das quadratische Glied kann hierbei im Allgemeinen vernachlässigt werden.

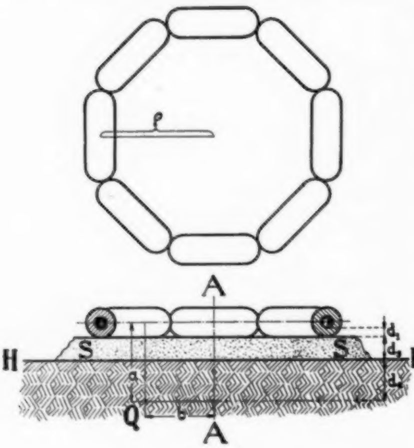


Fig. 11.

Handelt es sich um die Intensität auf die centrale Normale A—A (s. Fig. 11), so bietet es keine Schwierigkeit, auch die eben erwähnten cylindrischen Filter bei beliebig grossem d (eventuell $d_1 + d_2 + \ldots$) in die Berechnung aufzunehmen. Der Faktor $e^{-\Sigma \mu_K d}$ war in Formel (4) nur eingeführt, um die Cylinderfilter nicht ganz unberücksichtigt zu lassen. Wegen der Symetrie muss er jetzt aber als ziemlich genauer, den geometrischen Verhältnissen entsprechender Faktor auftreten. Folglich ergibt sich unter Vernachlässigung des quadratischen Gliedes, und wenn $b = 0$:

$$J_l = \frac{P}{a^2 + \varrho^2} \left[\frac{53}{100} f(a)_{K_1} + \frac{40}{100} f(a)_{K_2} + \frac{7}{100} f(a)_{K_3} \right]$$

wobei

$$\text{nach Figur 11:} \quad f(a)_K = e^{-\left[\Sigma \mu d + (\mu_s d_s + \mu_e d_e) \cdot \frac{\sqrt{a^2 + \varrho^2}}{a}\right]_K} \quad \ldots . (5)$$

$$\text{oder nach Figur 12:} \quad f(a)_K = e^{-\left[\Sigma \mu d + \mu_e \cdot \sqrt{a^2 + \varrho^2 - \Sigma d}\right]_K} \quad \ldots \ldots \ldots (6)$$

Kurve (r) in Diagramm II ist nach der Formel (6) berechnet. Konstanten sind dabei:

$P = 1$ mgr, $\varrho = 3$ cm, d_1 $[Ag] = 0.1$ cm, d_2 $[Pb] = 0.2$ cm, d_s [Dichte $= 2$] $= 0.5$ cm.

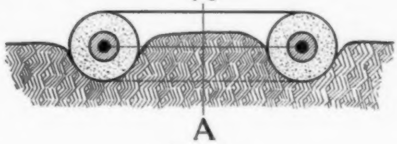


Fig. 12.

2. *Flächenpräparate.* Für diese sind die Formeln auf Seite 100 und 101 ohne weiteres verwendbar, nur muss die Dicke der Flächenbelegung im Vergleich zum Radius (R) und Abstand (a) gering sein, letzterer von der mittleren Schicht der Belegung aus gerechnet.

Am einfachsten ist die Berechnung für die Punkte der centralen Normale. Nach Formel (SD) wird nämlich:

$$J_l = \frac{2P}{R^2}\left[\frac{53}{100} f(a)_{K_1} + \frac{40}{100} f(a)_{K_2} + \frac{7}{100} f(a)_{K_3}\right] \quad \ldots . \quad (7)$$

wobei $f(a)_K = \Big[-Ei\,(-\Sigma\mu d)\Big]_K - \Big[-Ei\Big(-\Sigma\mu d\,\frac{\sqrt{a^2+R^2}}{a}\Big)\Big]_K.$

Die Werte von $-Ei(-x)$ sind der Tafel V zu entnehmen.

Kurve (f) in Diagramm II ist mit Hilfe dieser Formel aufgezeichnet worden, wobei $P = 1$ mgr, Radius $= 2$ cm, Filterstärke $= 0.1$ cm Silber $+ 0.2$ cm Sekundärfilter (Dichte $= 2$) sind.

In der Radiumtherapie sind die Flächenpräparate indessen meistens von rektangulärer Form. Durch Zerlegen des Präparates in runde Stücke kann man aber nach der oben erwähnten Formel die Strahlungsintensität hinreichend genau bestimmen. Für Präparate von quadratischer Form genügt wohl die Zerlegung im Sinne der Figur 13. Der infolge dieser Formveränderung der Strahlungsquelle hervorgerufene Fehler dürfte jedenfalls sehr gering sein.

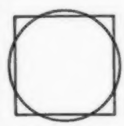


Fig. 13.

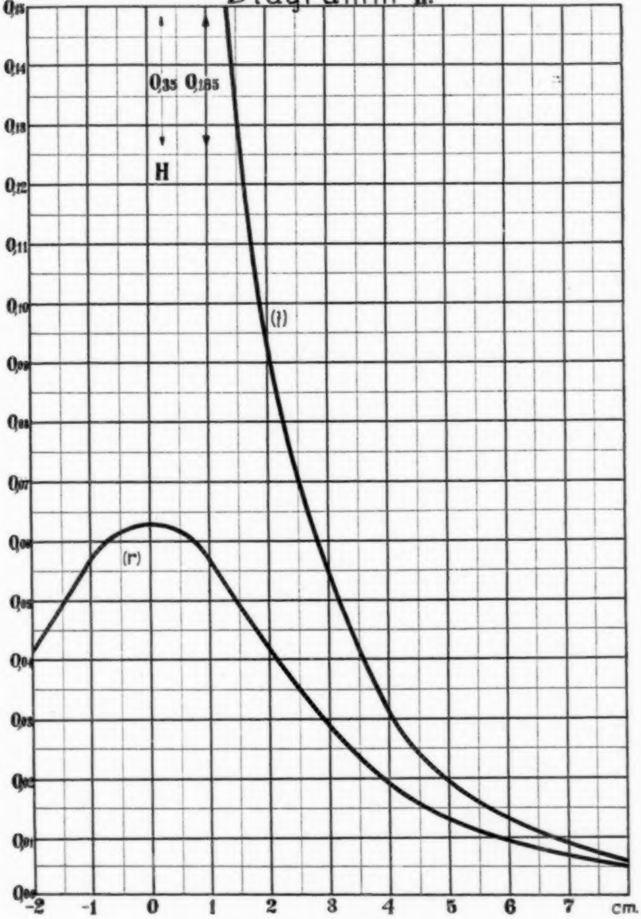
§ 6. Äquiintensitätsflächen.

Um die Intensitätsverteilung gut überblicken zu können, ist es in manchen Fällen von grossem Vorteil, die Form der Äquiintensitätsflächen zu kennen.

Die allgemeine Gleichung einer solchen Fläche ist:

$$J_l = J_k$$

Diagramm II.



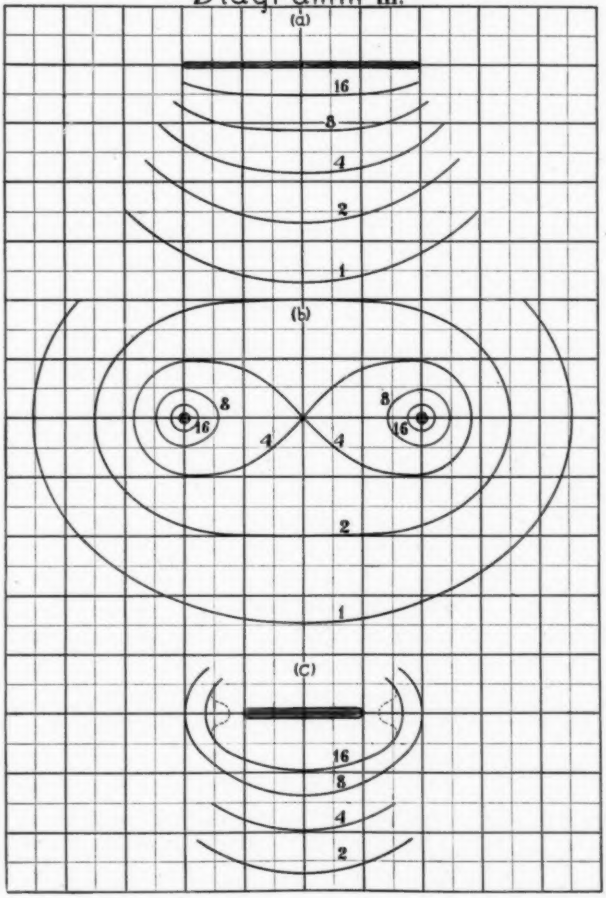
wobei für J_l der auf Seite 96 angegebene Ausdruck, für J_k die konstante Intensität der Fläche einzusetzen ist. Sind x, y und z die drei Koordinaten des Raumes, so kann man demnach

$$f\,(x,\ y,\ z) = J_k$$

schreiben.

Es sollen unten einige Formen dieser Flächen ohne Berücksichtigung der Absorption im Sekundärfilter und im Gewebe kurz besprochen werden.

Diagramm III.



Ist die Strahlungsquelle ein Rotationskörper, so genügt es, die Schnittkurven zu untersuchen, die von einer durch die Achse gelegte Ebene herausgeschnitten werden.

Für ein stabförmiges Präparat sind die Äquiintensitätsflächen ellipsoidähnlich. Es ist oft behauptet worden, dass infolge der Absorption in dem Radiumsalz selbst, die Flächen an den Enden Einbuchtungen (s. Diagramm III c, gestrichelte Linie) zeigen müssen. Dies ist unter der Voraussetzung, dass die Absorptionskoeffizienten des Salzes grösser sind,

als die des Filters, bei sehr geringer Filterstärke und Abstand allerdings der Fall. Mit Zunahme der Filterstärke und des Abstandes werden die Einbuchtungen aber allmählich flacher und bei Filtern von grösseren Absorptionskoeffizienten, als die des Radiumsalzes[1], ergeben sich sogar Erhöhungen statt Einbuchtungen.

Von grösserem Interesse sind die Äquiintensitätsflächen bei ringförmigem Applikator. Man erhält nach Formel (SC_1), also ohne Berücksichtigung irgend eines Filters, und wenn $a = y$ und $b = x$ gesetzt werden:

$$\frac{P}{J_k} = c^2 = \sqrt{(x^2 + y^2 + \varrho^2)^2 - 4\,x^2 \varrho^2}$$

oder

$$(x^2 + y^2)^2 - 2\,\varrho\,(x^2 - y^2) - c^4 = 0$$

Diese Gleichung repräsentiert so genannte Cassinische Kurven. Für $c^2 = 1$ erhält man eine 8-förmige Kurve (Lemniskate), für $c^2 < 1$ kreisähnliche Kurven, die den Querschnitt des Ringes umgeben. Bei $c^2 > 1$ geht die 8-förmige Kurve allmählich in ellipsen- und schliesslich in kreisähnliche Kurven über, die den ganzen Ring umhüllen.

Diagramm III b veranschaulicht diese verschiedenen Typen. Bei Berücksichtigung der Absorption werden die Kurven ein wenig deformiert, doch sind diese Veränderungen unwesentlich.

Die Äquiintensitätsflächen eines kreisrunden Flächenpräparates haben das in Diagramm III a dargestellte Aussehen.

In den drei in Diagramm III zusammengeführten Kurvenscharen sind die einzelnen Kurven mit den relativen Intensitäten 1, 2, 4 u. s. w. bezeichnet. Diese sind nur unter der Voraussetzung, dass alle drei Präparate die gleiche Totalmenge Radium enthalten, direkt untereinander vergleichbar.

§ 7. Dosenquotienten der primären γ-Strahlung.

Unter Dosenquotienten versteht man das Verhältnis der Intensitäten in zwei Punkten, die in derselben Strahlungsrichtung oder, wenn man so sagen darf, auf demselben »Strahl» liegen. Ist die Kurve des Intensitätsabfalles in einer gewissen Richtung gegeben, kann man natürlich die

---

[1] Diese Absorptionskoeffizienten dürften im Vergleich zu den von schweren Metallen nicht besonders gross sein. Die Dichte des Radiums kann durch Extrapolation aus der Beziehung zwischen Dichte und Atomgewicht von *Ca*, *Sr* und *Ba* = 6.0 (s. MEYER u. SCHWEIDLER (27), Seite 315) erhalten werden. Die Dichte der Radiumsalze kann wohl auch in kompaktem, wasserfreiem Zustand kaum mehr als 6—7 betragen. Durch Extrapolation aus den von KOHLRAUSCH (21) beobachteten Verhältnissen zwischen Absorptionskoeffiziénten und Dichten ergeben sich somit für die Radiumsalze folgende Maximalwerte:

$$\mu_{k_1} < 0.8,\ \mu_{k_2} < 1.5,\ \mu_{k_3} < 10.$$

Dosenquotienten für beliebige Punkte dieser Richtung berechnen. Die Intensitätskurven (Diagramm I u. II) geben also insofern einen Überblick über die Dosenquotienten, als je weniger steil die Kurve verläuft, desto mehr nähern sich diese der Zahl 1.

Experimenteller Teil

§ 8. Versuchsanordnung.

Um die Verteilung der γ-Strahlenintensität in geringen Entfernungen von medizinischen Radiumpräparaten durch Ionisation in Luft experimentell untersuchen zu können, erwies es sich als zweckmässig, eine Kompensationsmethode anzuwenden.

In Figur 14 ist die Versuchsanordnung schematisch dargestellt.

Der durch die γ-Strahlen in der »Mikroionisationskammer», M, hervorgerufene Ionenstrom konnte durch allmähliches Laden bezw. Entladen des Cylinderkondensators C kompensiert werden. Als Maass der Intensität diente also die Zeit, die zur Veränderung des Potential des Kondensators von einem konstanten Wert zum andern nötig war, ohne dass der Elektrometer wärend dieser Zeit von der Nulllage abwich. Die Veränderung des Potentials wurde durch langsame Bewegung des Schleifkontaktes S beim Schieberwiderstand W'_1, bewirkt. Der Kondensator war nämlich, wie es die Figur angibt, mit dem Stromkreis: Akkumulatorbatterie A, (200 Volt), Widerstand W_1, Erde G, Widerstand W'_1, verbunden. Das Präzisionsvoltmeter V zeigte die Potentialdifferenz (75—150 Volt) zwischen Kondensator und Erde. Die cylindrische, aus Aluminium-Folie hergestellte Wand der Ionisationskammer, e_2, konnte mit Hilfe einer Akkumulatorbatterie, A_2, auf + 60 bezw. — 60 Volt geladen werden. Der Diameter der Kammer betrug 9 mm, die Länge 7 mm. Den kleinen Elektroden e_1 bildete ein Messingsstift.

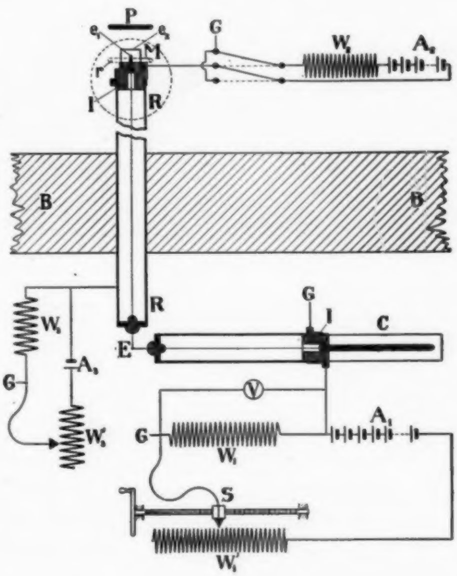


Fig. 14.

Um die von dem Kontaktpotential zwischen dem isolierten Messingsrohr, R, und dem Leitungsdraht hervorgerufenen Störungen zu eliminieren, konnte man auch Rohr R von einem Stromkreis A_3—W_3 aus auf das erforderliche Potential (0.03—0.04 Volt) laden.

Das Elektrometer, E, war ein »Balkenelektrometer» [s. ISING (16)] von sehr geringer Elektrodenkapazität. Mittelst eines Hebels mit isoliertem Griff konnte die Messelektrode geerdet werden. Die Empfindlichkeit betrug in den meisten Fällen ca. 10—15 Skalenteile pro Volt. Alle Zuleitungen waren gegen elektrostatische Einwirkungen durch geerdete, metallische Hüllen gut geschützt. Die ganze Messvorrichtung einschliesslich des Kondensators war hinter einem 5 cm dicken Bleischirm, B—B, aufgestellt. Der Abstand Radiumpräparat—Elektrometer betrug über 50 cm. Das Elektrometer war durch eine besondere Schutzwand von 3.5 cm Blei geschützt. Figur 15 zeigt das Aussehen des fertigen Apparates.

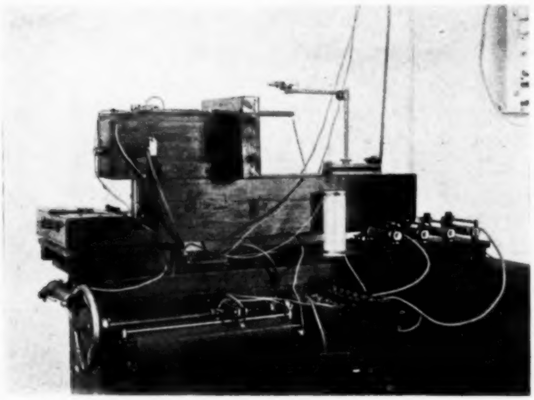


Fig. 15.

§ 9. Prüfung und Justierung des Apparates.

Ehe die unten beschriebenen Messungen zur Ausführung kamen, wurde der Apparat folgendermassen geprüft und justiert:

Das Elektrometer wurde zur Messung eingestellt: Ladung des Elektrometerfadens 600 Volt, die eine Elektrode geerdet, die andere mit dem Mess-System verbunden. Waren hierbei der Cylinderkondensator, die Ionisationskammer und das Rohr R alle geerdet, also ungeladen, so konnte selbst nach 10 Minuten noch keine Verschiebung des Elektrometerfadens beobachtet werden. Es wurde dann der Kondensator auf ca. 100 Volt geladen. Wärend der folgenden 2—5 Minuten verschob sich der Faden mit allmählich abnehmender, durchweg geringer Geschwindigkeit aus der 0-Lage. Eine ähnliche, aber etwas stärkere Bewegung war bei Ladung der Ionisationskammer wahrnehmbar. Der Grund dieser Erscheinung dürfte in der allmählichen Ladung der Bernsteinspfropfen I (s. Fig. 14) zu suchen sein, dies um so mehr, als die Bewegungsrichtung sich als von

dem Vorzeichen der Ladung abhängig erwies. Folglich bedurfte es nach jedem Ladungswechsel einer Pause von wenigstens 5 Minuten, ehe eine neue Messung angefangen werden konnte, was sich auch bei den eigentlichen Messungen bestätigte.

Zwecks Justierung des Potentials des Rohres R wurde alsdann ein starkes Radiumpräparat (ca. 20 mgr *Ra*) ungefähr auf $^1/_2$ cm Entfernung von der vorderen Wand der Ionisationskammer aufgehängt. Anfänglich war Rohr R geerdet. Der Ionenstrom wurde, wie oben angegeben, bei + 60 und bei — 60 Volt Kammerladung[1] durch Laden bezw. Entladen des Kondensators gemessen. In einem Falle waren z. B. die beobachteten Zeitwerte in Sekunden folgende:

	bei + 60 Volt	bei — 60 Volt
	45.0	40.2
	45.2	40.8
	45.2	41.0
	44.4	39.6
	44.6	40.4
Mittelwert	44.8	40.4
wahrscheinlicher Fehler	0.10	0.15

Nachdem R auf ein geeignetes Potential geladen war, ergab sich bei ähnlicher Messung:

	bei + 60 Volt	bei — 60 Volt
	42.2	42.6
	42.8	42.8
	42.0	42.8
	42.6	42.4
	42.8	42.4
Mittelwert	42.5	42.6
wahrscheinlicher Fehler	0.12	0.07

Da der Versuchsfehler also kleiner als 0.5 % zu sein schien, wurde die Einwirkung des Luftdruckes, die sogar mehrere Prozente ausmachen kann, als Korrektion berücksichtigt. Somit waren auch bei verschiedenen Barometerständen die beobachteten Werte vergleichbar. In dem hier in Frage kommenden Druckbereich kann die Ionisation als direkt proportional dem Luftdruck gesetzt werden.

Einige Versuche wurden dann ausgeführt, um die Einwirkung der Sekundärstrahlen zu beobachten, die von anderen Körpern, als der Elektrode e_1 und der Ionisationskammerwand e_2, ausgesandt wurden. Erstens wurde ein Messingsring ganz in die Nähe der Kammer gebracht (s. Fig. 14), dessen Masse ungefähr doppelt so gross war, als die Masse des in der Figur von einem gestrichelten Kreise angegeben Teiles des Apparates. Zweitens wurde ein grosses Stück Blei (ca. 10 kg) in ungefähr 15 cm

[1] Schon bei 40 Volt war der Sättigungsstrom, praktisch genommen, erreicht.

Abstand von der Kammer hingelegt. In beiden Fällen war die Abnahme der beobachteten Zeitwerte weniger als 2 %, selbst bei einem Abstand Radiumpräparat — Kammer von ca. 3 cm.

Es war somit festgestellt, dass die Sekundärstrahlung der Umgebung keinen nennenswerten Einfluss auf die relativen Messungen haben konnte. Indessen spielt, wie mehrere Forscher nachgewiesen haben (17), die weiche Sekundärstrahlung der Kammerwände, besonders bei kleinen Ionisationskammern, eine grosse Rolle. Ist aber die Zusammensetzung (Spektrum) der primären Strahlen bei den zu vergleichenden Messungen immer dieselbe, so dürften, wegen der geringen Grösse der Kammer, die erhaltenen Zeitwerte bei relativen Intensitätsmessungen jedoch gut vergleichbar sein, vorausgesetzt, dass die Sekundärstrahlung als direkt proportional der Primärstrahlung angenommen werden kann.

§ 10. Messresultate.

Bei den Messungen wurde ein stabförmiges Radiumbromid-Präparat von folgenden Dimensionen benutzt:

innere Länge	2.1	cm
innerer Diameter	0.15	»
Wandstärke:		
Gold	0.035	»
Platin	0.03	»
Inhalt an *Ra*-Element	23.6	mgr.

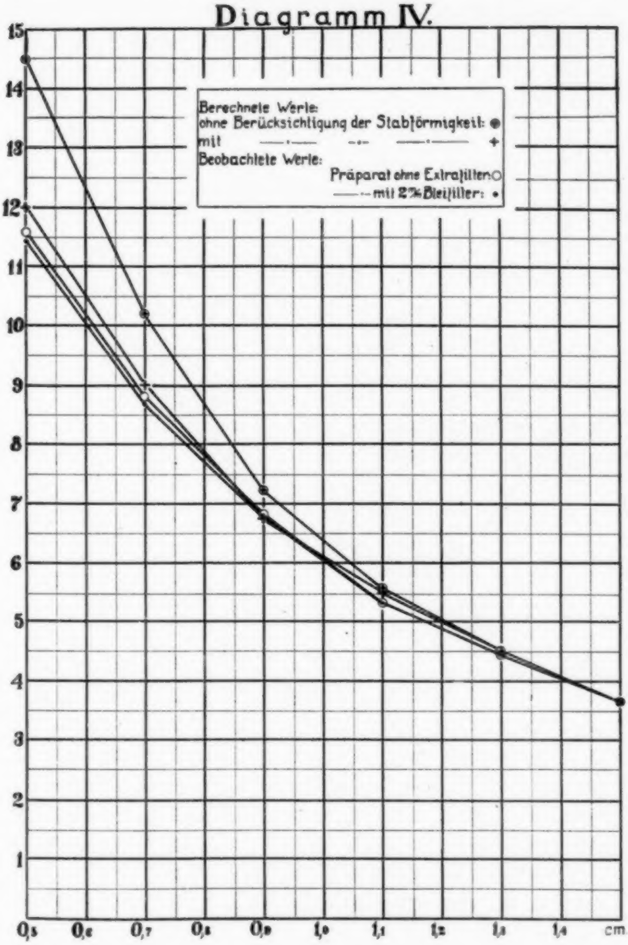
Das Präparat wurde in vertikaler Lage in ungefähr 5 mm Abstand von der Vorderwand der Ionisationskammer aufgehängt. Mittelst einer Mikrometerschraube konnte der Tubus in vertikaler Richtung verschoben werden. Durch Aufsuchen des Punktes, in welchem die Intensität am grössten war, wurde die »effektive Länge»[1] in dieser Lage mit 1 cm ermittelt. Einige andere Präparate, in derselben Weise untersucht, zeigten eine »effektive Länge» von $^1/_2$—$^2/_3$ der ganzen, inneren Länge.

Um die Richtigkeit der für stabförmige Präparate in § 5 benutzten Formel zu prüfen, wurde die Strahlung des Tubus, mit und ohne Extrafilter in verschiedenen Abständen gemessen. Hierbei befand sich der Mittelpunkt des Tubus in der Achse der Kammer, und der Abstand von deren Vorderwand konnte mit der wagrecht gerichteten Mikrometerschraube von 5 bis 15 mm verändert werden. Da das Radiumsalz den Hohlraum des Stabes etwa bis an den Mittelpunkt ausfüllte, musste die gemessene Intensität immer halb so gross sein, als wenn der Stab ganz gefüllt gewesen wäre.

Berücksichtigt man nun eine durch die Nichtpunktförmigkeit der Ionisationskammer notwendige Korrektion, so ergeben sich nach Formel (1)

[1] Länge der Salzsäule. Vergl. Anmerkung[1], Seite 102.

Diagramm IV.



die in Diagramm IV mit + bezeichneten, relativen Werte. Diese stimmen sehr gut mit den experimentell gefundenen Werten überein (s. Diagram IV.) Die Abweichung von den für die punktförmige Strahlungsquelle berechneten, relativen Intensitäten ist offenbar. Auch stimmt der kleine Unterschied zwischen den mit verschiedenen Filtern experimentell ermittelten Kurven gut mit den theoretischen Ergebnissen überein.

Das beobachtete Verhältnis der Intensiteten mit und ohne Extrafilter (0.2 cm Blei) wich von den berechneten um ungefähr 10 % ab. Es war

nämlich die Abschwächung infolge des Filters grösser, als nach Berechnung zu erwarten war. Diese Abweichung lässt sich wahrscheinlich auf die eben erwähnte, weiche Sekundärstrahlung der Kammerwände zurückführen, die hauptsächlich durch die beiden weicheren Komponenten K_2 und K_3 hervorgerufen werden, eine Tatsache, welche nach der beobachteten Richtung hin wirken muss.

Wie schon in der Einleitung ausgesprochen, muss man bei der γ-Strahlung annehmen, das auch die Sekundär-Strahlen für die Dosis eine gewisse Rolle spielen können. Folgende Untersuchung zeigt jedoch, dass diese bei Wasser bezw. Gewebeschichten von geringerer Dicke als 1.5 cm keinen nennenswerten Teil der Gesamtdosis auszumachen scheinen. Es wurde nämlich die Ionisationskammer in einen Kolben von 700 ccm Inhalt, wie in Figur 16 veranschaulicht, hineingesteckt, und die Intensität mit und ohne Wasserfüllung beobachtet. Als Mittelwerte von 5 Bestimmungen ergaben sich bei 0.4 und 1.5 cm dicker Wasserschicht die relativen Intensitätswerte:

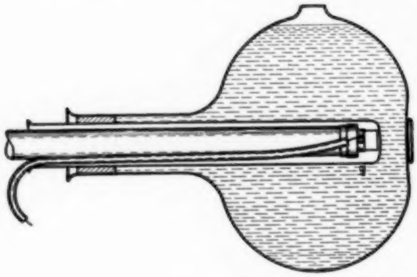


Fig. 16.

	ohne H_2O	mit H_2O
0.4 cm	198	193
1.5 »	69.3	61.3

Werden die obigen, »ohne H_2O» bezeichneten Werte einer Berechnung nach Formel (1) zugrunde gelegt, ergeben sich die relativen Werte:

	ohne H_2O	mit H_2O
0.4 cm	(198)	191
1.5 »	(69.3)	60.2

Die Sekundärstrahlenwirkung scheint also weniger als 1 besw. 1.8 % der Gesamtintensität zu sein, und dürfte deswegen in diesen Abständen bei den Dosenberechnungen vernachlässigt werden können. (Vergl. Seite 117 und 118.)

Einige Bemerkungen

Es sollen hier ganz kurz einige Punkte angeführt werden, die für die Dosenberechnung von besonderem Interesse sind:

Für die unmittelbare, praktische Anwendung der in vorliegender Arbeit beschriebenen Intensitätsberechnungen ist das Verhältnis der Sekundär-

strahlung ausschlaggebend. Gemäss den in § 10 wiedergegebenen Resultaten macht bei kleinen Abständen (0—2 cm) die Sekundärstrahlenintensität nur einen so geringen Teil der Gesamtintensität aus, dass sie vernachlässigt werden kann. Dieses Ergebnis ist aber gerade entgegengesetzt dem von FRIEDRICH und GLASSER (8) gefundenen. Bei deren Versuchen waren sowohl Ionisationskammer wie Präparat nach allen Richtungen hin mit mehr als 10 cm Wasser umgeben. Dabei erhielten sie folgende Werte:

Tabelle 4.

Nach FRIEDRICH und GLASSER (8).

Abstand in cm	Gemessene Dosis	Berechnete Dosis	Unterschied in % der berechneten Dosis
1	108.0	90.0	20.0
2	25.0	20.26	23.4
3	11.2	8.1	38.2
4	5.8	4.1	41.5
5	3.6	2.36	52.5
6	2.4	1.48	62.1
8	1.3	0.65	100.0
10	0.8	0.35	130.0

Bei dem Abstand 1 cm erhält man durch Interpolation aus den auf Seite 116 angeführten Werten ungefähr 1.5 % statt 20 % wiein Tabelle 4. Ein Teil des Unterschiedes ist sicher durch das bedeutend grössere, das Präparat ganz umhüllende Wasservolumen hervorgerufen, wodurch aber die Sekundärstrahlung kaum mehr als verdreifacht werden kann, also von 1.5 bis etwa 5 %. Ein anderer Grund, der vielleicht eine Erklärung bietet, liegt in die Verschiedenheit der Filterung der Sekundärstrahlung. Das bei vorliegender Untersuchung benutzte Glasrohr (s. Fig. 16, g) absorbiert einen grossen Teil der weichsten Sekundärstrahlung. Diese weiche Strahlung dürfte aber wegen ihrer geringen Reichweite als direkt proportional der Primärstrahlenintensität in dem bestrahlten Raumelement gesetzt werden können und deshalb für die Dosenberechnung von weniger Interesse sein. Schliesslich ist in der Abhandlung von FRIEDRICH und GLASSER (8) nicht angegeben, welche Absorptionskoeffizienten den Berechnungen zugrunde gelegt sind. Mit den hier benutzen Koeffizienten erhält man jedenfalls ganz andere Werte, als die

»berechneten Dosen» der Tabelle 4. So ergibt sich z. B. bei 10 cm Abstand die »berechnete Dosis» mit 0.47 statt 0.35 in der Tabelle. Der Wert 130.0 % geht somit in 70 % über. Es wird nicht der Anspruch erhoben, dass die in vorliegender Arbeit beschriebenen Sekundärstrahlenmessungen einwandfrei seien. Vielmehr bestätigt der Mangel an Übereinstimmung die schon mehrmals ausgesprochene Behauptung, dass bei radioaktiven Messungen die Ergebnisse leider sehr von der Versuchsanordnung abhängig sind. Um, wenn möglich, in der Frage zu einer Entscheidung zu gelangen, wird die Untersuchung der Sekundärstrahlen fortgesetzt, und soll über das Ergebnis später berichtet werden.

Bei den eigentlichen Berechnungen dürfte es von Interesse sein, die Intensitäten der verschiedenen Strahlungskomponenten einzeln aufzuführen. Die Möglichkeit ist ja nicht ganz ausgeschlossen, dass die physiologische Wirkung der verschiedenen Komponenten eine verschiedene sein könnte.

Will man die Gesamtintensität nur überschlagsweise bestimmen, so kann mann die, unter Berücksichtigung der Intensitätsverhältnisse 8: 6: 1 ausgerechneten Mittelwerte der Absorptionskoeffizienten (s. Tafel I, $\mu_{med.}$) anwenden, und somit die Berechnung vereinfachen.

Die Hohlräume der stabförmigen Präparate sind sehr oft nicht ganz mit Radiumsalz ausgefüllt, wenigstens scheint dies bei den Präparaten des hiesigen Radiuminstitutes der Fall zu sein, ein Übelstand, dem wohl leicht abgeholfen werden könnte, etwa durch Einbacken des Salzes in irgend eine plastiche Masse. Wie gross die Veränderungen der Intensitäten in den verschieden Lagen der Präparate infolge dieses Umstandes sein können, geht aus folgendem Beispiel deutlich hervor: Ein halbgefüllter, 3 cm langer Tubus wird das eine Mal in senkrechter, das andere Mal in wagrechter Lage bei 4 mm Entfernung von der Haut (von der Achse des Tubus aus gerechnet), parallel zu dieser, benutzt. Die maximale Intensität auf der Haut wird im ersten Falle ungefähr doppelt so gross sein wie im zweiten.

Was die verschiedenen Applikatoren betrifft, so besitzt der auf Seite 106 und 107 angeführte (s. Fig. 12), ringförmige Typus eine besonders gute Verteilung der Intensität. Ist es möglich, den Tumor ein wenig in den Ring hineinzuziehen, erhält man, wie aus Diagramm III b ersichtlich, eine sehr gleichmässige Bestrahlung, wobei die Ränder des Tumors die stärkste Dosis bekommen.

Natürlich ist bei allen Applikatoren in Betracht zu ziehen, dass mit wachsendem Abstand die Abweichung vom Quadratgesetz immer geringer wird. Von einem durch die verlangte Genauigkeit bestimmten Abstand an sind also die Formeln (A 1) und (A 2) zu benutzen. Die Abweichung beträgt z. B. bei stabförmigen Präparaten, auf der Mittelpunktsnormale nur 8—9 %, wenn Abstand $(a) =$ Tubuslänge (l).

Zur Orientierung seien schliesslich folgende, nach den Angaben von Seitz und Wintz (34) berechnete Werte der »Cancer-Dosis» angeführt:

Bestrahlungszeit in Stunden:	Erforderliche Intensität in *MCS*:
20	15
30	11
40	9

Zusammenfassung

Unter Berücksichtigung der Absorption und »Dispersion» sind einige Formeln für die Berechnung der γ-Strahlenintensität der Primär-Strahlen, bei Strahlungsquellen verschiedener Form, abgeleitet worden.

Um diese Formeln in der Radiumtherapie verwenden zu können, sind einige Tabellen zusammengestellt worden.

Die relativen Intensitäten bei verschiedenen Abständen von einem stabförmigen Präparat sind mittelst einer Ionisationsmethode untersucht worden. Die beobachteten Werte stimmen mit den berechneten gut überein.

Die Sekundärstrahlung von Wasser ist nach Durchgang durch ca. 1 mm Glas bei 0—2 cm Abstand gemessen worden, und erwies es sich, dass diese weniger als 2 % der Gesamtintensität betrug.

Zum Schluss möchte ich Herrn Prof. Dr. G. Forssell, auf dessen Anregung vorliegende Arbeit zustandegekommen ist, für gütiges Ausleihen der Radiumpräparate, wie auch Herrn Dozent G. Ising für seine guten Ratschläge und für die Freundlichkeit, mir einen seiner ausgezeichneten Elektrometer zur Verfügung gestellt zu haben, meinen besten Dank aussprechen.

Auch bin ich dem Vorsteher des Nobelinstitutes für physikalische Chemie, in welchem der experimentelle Teil ausgeführt worden ist, Herrn Prof. S. Arrhenius, vielen Dank schuldig.

Tafel I.

Absorptionskoeffizienten nach Kohlrausch (21).

Stoff	Dichte	μ_{K_1}	μ_{K_2}	μ_{K_3}	$\mu_{med.}$
Wasser	1	0.055	0.100	0.2 ·)	0.08
Gewebe	1.1	0.06 ·)	0.11 ·)	0.25 ·)	0.09
Aluminium	2.7	0.13	0.23	0.57	0.19
Zink	7.2	0.32	0.57	1.44	0.5
Zinn	7.3	0.30	0.69	1.5 ·)	0·5
Eisen	7.9	0.36	0.63	3.0	0.6
Messing	8.4	0.37 [1]	0.66 [1]	3 ·)	0.6
Neusilber	8.5	0.38 [1]	0.68 [1]	3 ·)	0.7
Kupfer	8.9	0.40	0.70	3 ·)	0.7
Nickel	8.9	0.41	0.75	3 ·)	0.7
Silber	10.5	0.45	0.99	4 ·)	0.9
Blei	11.3	0.53	1.49	4.6	1.1
Quecksilber	13.6	0.62	1.73	5 ·)	1.3
Gold	19.3	0.90	2.3	7 ·)	1.9
Platin	21.4	1.0 ·)	2.5 ·)	7 ·)	2
Ra-Salze	6	0.2—0.3 ·)	1—1.5 ·)	5—10 ·)	0.8—1.4

[1] Diese Werte sind unter Voraussetzung, dass die Absorption eine Atomeigenschaft ist, also additiv verläuft, aus den Absorptionskoeffizienten der Bestandteile errechnet.

·) Durch Interpolation bezw. Extrapolation aus den Kohlrausch'schen Werten ermittelt. Die Werte von μ_{K_3} dürften sehr unzuverlässig sein, weil hier selektive Effekte auftreten können.

Tafel II.

e^{-x}.

x	0	1	2	3	4	5	6	7	8	9
0.00	1.0000	0.9990	0.9980	0.9970	0.9960	0.9950	0.9940	0.9930	0.9920	0.9910
.0	1.0000	0.9900	0.9802	0.9704	0.9608	0.9512	0.9418	0.9324	0.9231	0.9139
.1	0.9048	.8958	.8869	.8781	.8693	.8607	.8522	.8437	.8353	.8270
.2	.8187	.8106	.8025	.7945	.7867	.7788	.7711	.7634	.7558	.7483
.3	.7408	.7335	.7262	.7189	.7118	.7047	.6977	.6908	.6839	.6770
.4	.6703	.6637	.6570	.6505	.6440	.6376	.6313	.6250	.6188	.6126
.5	.6065	.6005	.5945	.5886	.5828	.5769	.5712	.5655	.5599	.5543
.6	.5488	.5434	.5380	.5326	.5273	.5221	.5168	.5117	.5066	.5016
.7	.4966	.4916	.4868	.4819	.4771	.4724	.4677	.4630	.4584	.4538
.8	.4493	.4449	.4404	.4361	.4317	.4274	.4232	.4190	.4148	.4107
.9	.4066	.4025	.3985	.3946	.3906	.3867	.3829	.3791	.3753	.3716
1.	0.3679	0.3329	0.3012	0.2725	0.2466	0.2231	0.2019	0.1827	0.1653	0.1496
2.	.1353	.1225	.1108	.1003	.0907	.0821	.0743	.0672	.0608	.0550
3.	.0498	.0451	.0408	.0369	.0334	.0302	.0273	.0247	.0224	.0202
4.	.0183	.0166	.0150	.0136	.0123	.0111	.0101	.0091	.0082	.0074
5.	.0067	.0061	.0055	.0050	.0045	.0041	.0037	.0033	.0030	.0027
6.	.0025	.0022	.0020	.0018	.0017	0015	.0014	.0012	.0011	.0010
7.	.0009	—	—	—	—	—	—	—	—	—
8.	.0003	—	—	—	—	—	—	—	—	—
9.	.0001	—	—	—	—	—	—	—	—	—
10.	.0000	—	—	—	—	—	—	—	—	—

Tafel

$$\mathfrak{F}(\varphi) = \int_0^{\varphi} e^{-\frac{\Sigma\mu d}{\cos\varphi}} \cdot d\varphi$$ nach graphischer

$tg\,\varphi$	0.087	0.176	0.268	0.364	0.466	0.577	0.700	0.839	1.000
φ	5°	10°	15°	20°	25°	30°	35°	40°	45°
$\Sigma\mu d = 0.00$	0.087	0.175	0.263	0.349	0.436	0.524	0.611	0.698	0.785
.01	.086	.173	.259	.346	.432	.518	.605	.691	.778
.02	.086	.171	.257	.342	.428	.513	.599	.684	.769
.03	.085	.169	.254	.339	.423	.507	.592	.675	.759
.04	.084	.168	.251	.335	.418	.502	.585	.668	.750
.05	.083	.166	.249	.332	.414	.497	.579	.661	.743
.06	.082	.164	.246	.328	.410	.492	.574	.654	.735
.08	.081	.161	.241	.321	.401	.481	.560	.639	.717
.10	.079	.156	.236	.315	.393	.471	.548	.626	.702
.15	.075	.150	.225	.300	.374	.447	.520	.593	.664
.20	.071	.143	.213	.284	.354	.424	.493	.561	.627
.25	.068	.136	.203	.270	.336	.402	.470	.534	.596
.3	.065	.129	.193	.257	.320	.382	.443	.504	.561
.4	.058	.117	.175	.232	.289	.345	.399	.452	.502
.5	.053	.105	.158	.209	.260	.310	.359	.405	.450
.6	.048	.096	.143	.189	.234	.279	.322	.362	.401
.8	.039	.078	.116	.154	.191	.226	.260	.292	.322
1.0	.032	.064	.095	.125	.154	.182	.209	.234	.257
1.5	.019	.038	.057	.075	.092	.108	.123	.136	.148
2.0	.012	.023	.035	.045	.056	.065	.073	.080	.085
2.5	.007	.014	.021	.027	.033	.038	.043	.046	.049
3.	.004	.009	.013	.016	.020	.023	.025	.027	.029
4.	.002	.003	.005	.006	.007	.008	.009	.009	.010
5.	.001	.001	.002	.002	.003	.003	.003	.003	.003

III.

Methode berechnet. (Fehler < 0.2 %).

1.000	1.192	1.428	1.732	2.145	2,748	3.732	5.671	11.430	$tg\,\varphi$
45°	50°	55°	60°	65°	70°	75°	80°	85°	φ
0.785	0.873	0.960	1.047	1.134	1.222	1.309	1.396	1.484	$0.00 = \Sigma\mu d$
.778	.864	.950	1.036	1.121	1.207	1.292	1.375	1.457	.01
.769	.853	.938	1.022	1.106	1.189	1.271	1.351	1.425	.02
.759	.843	.926	1.008	1.090	1.171	1.250	1.326	1.395	.03
.750	.833	.915	0.996	1.076	1.154	1.231	1.304	1.367	.04
.743	824	.904	.984	1.062	1.138	1.213	1.282	1.341	.05
.735	.815	.894	.972	1.049	1.124	1.195	1.261	1.315	.06
.717	.795	.872	.947	1.021	1.091	1.158	1.220	1.265	.08
.702	.777	.851	.923	0.993	1.060	1.123	1.178	1.217	.10
.664	.734	.802	.869	.932	0.990	1.044	1.087	1.114	.15
.627	.693	.756	.816	.873	.924	0.969	1.004	1.024	.20
.596	.656	.714	.769	.819	.865	.903	0.931	0.944	.25
.561	.617	.670	.720	.765	.805	.838	.861	.870	.3
.502	.550	.595	.637	.634	.704	.727	.741	.745	.4
.450	.492	.530	.565	.594	.618	.634	.643	.646	.5
.401	.437	.469	.498	.522	.540	.552	.558	.559	.6
.322	.348	.372	.392	.408	.418	.424	.426	.426	.8
.257	.277	.293	.307	.317	.323	.326	.332	.332	1.0
.148	.157	.164	.169	.172	.174	.175	.175	.175	1.5
.085	.090	.094	.096	.097	.097	.097	.097	.097	2.0
.049	.052	.053	.054	.054	.055	.055	.055	.055	2.5
.029	.030	.030	.031	.031	.031	.031	.031	.031	3.
.010	.010	.010	.010	.010	.010	.010	.010	.010	4.
.003	.003	.003	.003	.003	.003	.003	.003	.003	5.

Tafel IV.

$$\mathfrak{E}(x) = \int_x^\infty \frac{e^{-x}}{x^2}\,dx$$ nach MILLER und ROSEBRUGH (28).

x	$\mathfrak{E}(x)$	x	$\mathfrak{E}(x)$	x	$\mathfrak{E}(x)$
0.10	7.2255	0.36	1.1635	1.10	0.1166
.11	6.4068	.37	1.1114	1.15	.1038
.12	5.7315	.38	1.0625	1.20	.0926
.13	5.1657	.39	1.0166	1.25	.0828
.14	4.6856	.40	0.9734	1.30	.0742
.15	4.2736	.41	.9327	1.35	.0666
.16	3.9167	.42	.8944	1.40	.0599
.17	3.6050	.43	.8582	1.45	.0540
.18	3.3306	.44	.8240	1.5	.0487
.19	3.0876	.45	.7916	1.6	.0399
.20	2.8710	.46	.7610	1.7	.0328
.21	2.6770	.47	.7319	1.8	.0271
.22	2.5024	.48	.7043	1.9	.0225
.23	2.3446	.49	.6782	2.0	.0188
.24	2.2014	.50	.6533	2.1	[1] .0157
.25	2.0709	.55	.5456	2.2	[1] .0132
.26	1.9517	.60	.4603	2.3	[1] .0110
.27	1.8424	.65	.3916	2.4	[1] .0092
.28	1.7419	.70	.3356	2.5	[1] 0077
.29	1.6493	.75	.2895	2.6	[1] .0065
.30	1.5637	.80	.2511	2.7	[1] .0054
.31	1.4845	.85	.2188	2.8	[1] .0045
.32	1.4109	.90	.1916	2.9	[1] .0038
.33	1.3425	.95	.1684	3.0	[1] .0032
.34	1.2787	1.00	.1485	3.5	[1] .0012
.35	1.2192	1.05	.1314	4.0	[1] .0003

[1] Diese Werte sind nicht bei MILLER und ROSEBRUGH zu finden, sondern sind besonders für diesen Zweck berechnet worden.

Tafel V.

$-Ei(-x) = \int_x^\infty \frac{e^{-x}}{x} dx$ nach Miller und Rosebrugh (28) [0.001—2] und Glaisher (9) [2—10].

x	0	1	2	3	4	5	6	7	8	9
0.00	∞	6.3315	5.6394	5.2349	4.9482	4.7261	4.5448	4.3916	4.2591	4.1423
.01	4.0379	3.9436	3.8576	3.7786	3.7054	3.6374	3.5739	3.5142	3.4581	3.4050
.02	3.3547	3.3069	3.2614	3.2179	3.1763	3.1365	3.0983	3.0615	3.0261	2.9920
.03	2.9591	2.9273	2.8967	2.8668	2.8379	2.8099	2.7827	2.7563	2.7306	2.7056
.04	2.6813	2.6576	2.6344	2.6119	2.5899	2.5684	2.5474	2.5268	2.5069	2.4871
.05	2.4679	2.4491	2.4306	2.4126	2.3948	2.3775	2.3604	2.3460	2.3273	2.3111
.06	2.2953	2.2797	2.2645	2.2494	2.2346	2.2201	2.2058	2.1917	2.1779	2.1643
.07	2.1508	2.1376	2.1246	2.1118	2.0991	2.0867	2.0744	2.0623	2.0503	2.0386
.08	2.0269	2.0155	2.0042	1.9930	1.9820	1.9711	1.9604	1.9498	1.9393	1.9290
.09	1.9187	1.9087	1.8987	1.8888	1.8791	1.8695	1.8599	1.8505	1.8412	1.8320
.10	1.8229	1.8139	1.8050	1.7962	1.7875	1.7789	1.7704	1.7619	1.7536	1.7453
.11	1.7371	1.7290	1.7210	1.7130	1.7052	1.6974	1.6897	1.6820	1.6745	1.6670
.12	1.6595	1.6522	1.6449	1.6377	1.6305	1.6234	1.6164	1.6094	1.6025	1.5957
.13	1.5889	1.5822	1.5755	1.5689	1.5623	1.5558	1.5494	1.5430	1.5367	1.5304
.14	1.5241	1.5180	1.5118	1.5057	1.4997	1.4937	1.4878	1.4819	1.4760	1.4702
.15	1.4645	1.4587	1.4531	1.4474	1.4419	1.4363	1.4308	1.4253	1.4199	1.4145
.16	1.4092	1.4039	1.3986	1.3934	1.3882	1.3830	1.3779	1.3728	1.3678	1.3628
.17	1.3578	1.3528	1.3479	1.3430	1.3382	1.3334	1.3286	1.3239	1.3191	1.3145
.18	1.3098	1.3052	1.3006	1.2960	1.2915	1.2870	1.2825	1.2780	1.2736	1.2692
.19	1.2649	1.2605	1.2562	1.2519	1.2477	1.2434	1.2392	1.2350	1.2309	1.2268
.20	1.2227	1.2186	1.2145	1.2105	1.2065	1.2025	1.1985	1.1946	1.1907	1.1868
.21	1.1829	1.1791	1.1752	1.1714	1.1676	1.1639	1.1601	1.1564	1.1527	1.1490
.22	1.1454	1.1417	1.1381	1.1345	1.1309	1.1274	1.1239	1.1203	1.1168	1.1133
.23	1.1099	1.1064	1.1030	1.0996	1.0962	1.0928	1.0895	1.0861	1.0828	1.0795
.24	1.0762	1.0730	1.0697	1.0665	1.0633	1.0601	1.0569	1.0537	1.0505	1.0474
.25	1.0443	1.0412	1.0381	1.0350	1.0319	1.0289	1.0259	1.0229	1.0198	1.0169
.26	1.0139	1.0109	1.0080	1.0051	1.0021	0.9992	0.9963	0.9935	0.9906	0.9878
.27	0.9849	0.9821	0.9793	0.9765	0.9737	.9710	.9682	.9655	.9627	.9600
.28	.9573	.9546	.9519	.9493	.9466	.9440	.9413	.9387	.9361	.9335
.29	.9309	.9283	.9258	.9232	.9207	.9182	.9156	.9131	.9106	.9082
.30	.9057	.9032	.9008	.8983	.8959	.8935	.8911	.8886	.8863	.8839
.31	.8815	.8791	.8768	.8745	.8721	.8698	.8675	.8652	.8629	.8606
.32	.8583	.8561	.8538	.8516	.8493	.8471	.8449	.8427	.8405	.8383
.33	.8361	.8339	.8318	.8296	.8275	.8253	.8232	.8211	.8189	.8168
.34	.8147	.8127	.8106	.8085	.8064	.8044	.8023	.8003	.7983	.7962
.35	.7942	.7922	.7902	.7882	.7862	.7842	.7823	.7803	.7784	.7764

x	0	1	2	3	4	5	6	7	8	9
0·35	0.7942	0.7922	0.7902	0.7882	0.7862	0.7842	0.7823	0.7803	0.7784	0.7764
.36	.7745	.7725	.7706	.7687	.7668	.7649	.7630	.7611	.7592	.7573
.37	.7554	.7536	.7517	.7499	.7480	.7462	.7444	.7425	.7407	.7389
.38	.7371	.7353	.7335	.7317	.7300	.7282	.7264	.7247	.7229	.7212
.39	.7194	.7177	.7160	.7143	.7125	.7108	.7091	.7074	.7057	.7041
.40	.7024	.7007	.6990	.6974	.6957	.6941	.6924	.6908	.6892	.6875
.41	.6859	.6843	.6827	.6811	.6795	.6779	.6763	.6747	.6731	.6716
.42	.6700	.6684	.6669	.6653	.6638	.6622	.6607	.6592	.6576	.6561
.43	.6546	.6531	.6516	.6501	.6486	.6471	.6456	.6441	.6427	.6412
.44	.6397	.6383	.6368	.6354	.6339	.6325	.6310	.6296	.6282	.6268
.45	.6253	.6239	.6225	.6211	.6197	.6183	.6169	.6155	.6141	.6128
.46	.6114	.6100	.6087	.6073	.6059	.6046	.6032	.6019	.6005	.5992
.47	.5979	.5965	.5952	.5939	.5926	.5913	.5900	.5887	.5874	.5861
.48	.5848	.5835	.5822	.5809	.5797	.5784	.5771	.5759	.5746	.5733
·49	.5721	.5708	.5696	.5684	.5671	.5659	.5647	.5634	5622	.5610
.50	.5598	.5586	.5574	.5562	.5550	.5538	.5526	.5514	.5502	.5490
0.5	0.5598	0.5478	0.5362	0.5250	0.5140	0.5034	0.4930	0.4830	0.4732	0.4636
.6	.4544	.4454	.4366	.4280	.4197	.4115	.4036	.3959	.3883	.3810
.7	.3788	.3668	.3599	.3532	.3467	.3403	.3341	.3280	.3221	.3163
.8	.3106	.3050	.2996	.2943	.2891	.2840	.2790	.2742	.2694	.2647
.9	.2602	.2557	.2513	.2470	.2429	.2387	.2347	.2308	.2269	.2231
1.0	.2194	.2157	.2122	.2087	.2052	.2019	.1986	.1953	.1922	.1890
1.1	.1860	.1830	.1801	.1772	.1743	.1716	.1688	.1662	.1635	.1609
1.2	.1584	.1559	.1535	.1511	.1487	.1464	.1441	.1419	.1397	.1376
1.3	.1355	.1334	.1313	.1293	.1274	.1254	.1235	.1216	.1198	.1180
1.4	.1162	.1145	.1128	.1111	.1094	.1078	.1062	.1046	.1030	.1015
1.5	.1000	.0985	.0971	.0957	.0943	.0929	.0915	.0902	.0889	.0876
1.6	.0863	.0851	.0838	.0826	.0814	.0802	.0791	.0780	.0768	.0757
1.7	.0747	.0736	.0725	.0715	.0705	.0695	.0685	.0675	.0666	.0656
1.8	.0647	.0638	.0629	.0620	.0612	.0603	.0595	.0586	.0578	.0570
1.9	.0562	.0554	.0547	.0539	.0531	.0524	.0517	.0510	.0503	.0496
2.	0.0489	0.0426	0.0372	0.0325	0.0284	0.0249	0.0219	0.0192	0.0169	0.0148
3.	.0130	.0115	.0101	.0089	.0079	.0070	.0062	.0054	.0048	.0043
4.	.0038	.0033	.0030	.0026	.0023	.0021	.0018	.0016	.0015	.0013
5.	.001148	—	—	—	—	—	—	—	—	—
6.	.000360	—	—	—	—	—	—	—	—	—
7.	.000115	—	—	—	—	—	—	—	—	—
8.	.000038	—	—	—	—	—	—	—	—	—
9.	.000012	—	—	—	—	—	—	—	—	—
10.	.000004	—	—	—	—	—	—	—	—	—

Literaturverzeichnis

1. Amreich, I.: Untersuchungen über die Verbesserungsfähigkeit der Radiumtiefentherapie des Kollumkarzinoms. Strahlentherapie, 10, S. 802, 1920.
2. Blau, M.: Über die Absorption divergenter γ-Strahlung. Wien. Ber. 127, S. 1253, 1918.
3. Chadwich, J.: The Absorption of γ-Rays by Gases and Light Substances. Proc. Roy. Soc. London, 24, S. 152, 1912 und Le Radium, 9, S. 200, 1912.
4. Christen, Th.: Sekundärstrahlen und Härtegrad. Fortschr. a. d. Geb. d. Röntgenstr. 25, S. 55, 1917.
5. Dessauer, F.: Die physikalischen und thechnischen Grundlagen bei der Radiumbestrahlung und Röntgenbestrahlung. Strahlentherapie, 4, S. 452, 1914.
6. Eve, H.: On the Number of Ions produced by the Beta Rays and by the Gamma Rays from Radium C. Phil. Mag. 22, S. 551, 1911.
7. — —: On the Number of Ions produced by the Gamma Radiation from Radium. Phil. Mag. 27, S. 394, 1914.
8. Friedrich, W. und O. Glasser. Über die Dosenverhältnisse bei inkorporaler Radium- und Mesothoriumtherapie. Strahlentherapie, 11, S. 20, 1920.
9. Glaisher, J. W. L.: Tables of the Numerical Values of the Sine-integral, Cosine-integral, and Exponential-integral. Phil. Transact. of the Roy. Soc. of London, 160, II, S. 367, 1870.
10. Glasser, O.: Über die Bedeutung der Filterung auf die Dosenverhältnisse bei inkorporaler Radium- und Mesothoriumbehandlung. Strahlentherapie, 12. S. 256, 1921.
11. Glocker, R.: Über Absorption und Streuung der Röntgenstrahlen. Fortschr. a. d. Geb. d. Röntgenstr. 25, S. 421, 1918.
12. — — und M. Kaupp. Die Berechnung des Absorptionsverlustes der Streustrahlung innerhalb des streuenden Körpers. Physik. ZS. 22, S. 200, 1921.
13. Greinacher, H.: Über die Strahlenverteilung an radioaktiven Körpern. Physik. ZS. 9, S. 385, 1908 und 10, S. 145, 1909.
14. Habs, .: Probleme der Therapie mit radioaktiven Substanzen. Strahlentherapie, 7, S. 809, 1916.
15. Hess, V. F.: Über die Absorption der γ-Strahlen von Radium C in der Atmosphäre. Physik. ZS. 12, S. 998, 1911.
16. Ising, G. A.: Undersökningar rörande elektrometrar. Diss. Lund, I, 1917 und II, 1919.
17. Keetman, B.: Die Absorption der γ-Strahlen. Ann. der Physik. 52, S. 709, 1917.
18. Kehrer, E.: Über Tiefenwirkung und Reizdosierung des Radiums bei der Karzinombestrahlung. Münch. Med. Woch. 65, S. 719, 1918.
19. — —: Die Radiumbestrahlung bösartiger Neubildungen. Verh. der Deutschen Ges. für Gyn. Referate, S. 3, 1920.
20. King, L. V.: Absorption Problems in Radioaktivity. Phil. Mag. 23, S. 242, 1912.
21. Kohlrausch, K. W. F.: Die Absorption der γ-Strahlen von Radium. Wien. Ber. 126, S. 441, 1917 und 126, S. 683, 1917. Jahrbuch der Radioakt. und Elektronik, 15, S. 64, 1918.

22. Kohlrausch, K. W. F.: Über die harte Sekundärstrahlung der γ-Strahlung von Radium. Wien. Ber. 126, S. 705, 1917 und 128, S. 853, 1919.
23. — —: Die Streuung der γ-Strahlung. Phys. ZS. 21, S. 193, 1920.
24. Krönig, B. und W. Friedrich: Physikalische und biologische Grundlagen der Strahlentherapie, 1918.
25. Lahm, W.: Vorschläge zur Vereinheitlichung der Dosenangabe in der Radiumtherapie. Fortschr. a. d. Geb. d. Röntgenstr. 27, S. 442, 1920.
26. Matzdorff, P.: Vorschläge zur Vereinheitlichung der Dosenangabe in der Radiumtherapie. Fortschr. a. d. Geb. d. Röntgenstr. 27, S. 297, 1920 und 27, S. 556, 1920.
27. Meyer, St. und E. v. Schweidler: Radioaktivität. 1916.
28. Miller, W. L. und T. R. Rosebrugh: Numerical Values of Certain Functions involving e^{-x}. Proc. and Transact. of the Roy. Soc. of Canada, 9, III, S. 73, 1903.
29. Moseley, W. und K. Robinson: The Number of Ions produced by the β- and γ-Radiation from Radium. Phil. Mag. 28, S. 327, 1914.
30. Opitz, E. und W. Friedrich: Die Freiburger Strahlenbehandlung des Uteruskrebses. Münch. Med. Woch. 67, S. 1, 1920.
31. Rutherford, E.: Distribution of the Intensity of the Radiation from Radioactive Sources. Phil. Mag. 12, S. 152, 1906.
32. Schmidt, H. W.: Über die Strahlenverteilung an radioaktiven Körpern. Physik. ZS. 9, S. 537, 1908.
33. v. Schweidler, E.: Über die Strahlung einer von radioaktiver Materie erfüllten Kugel. Physik. ZS. 13, S. 453, 1912.
34. Seitz, L. und H. Wintz: Die kombinierte Röntgen-Radiumbehandlung im Rahmen der biologischen Dosierung. Zentralbl. f. Gyn. 44, S. 529, 1920.
35. v. Seuffert, E.: Praktische Bedeutung der Abweichung vom Dispersionsgesetz bei Radium-Therapie. Strahlentherapie, 11, S. 944, 1920.
36. Szmidt, J.: On the Distribution of Energy in the Different Types of Rays emitted from Certain Radioactive Substances. Phil. Mag. 28, S. 527, 1914.
37. Thirring, H.: Über den Einfluss der Absorption im Innern eines radioaktiven Präparats auf die ausgesendete Strahlung. Physik. ZS. 13, S. 266, 1912.

von

der

um-

um-
27,

ons
III,

and

rus-

tive

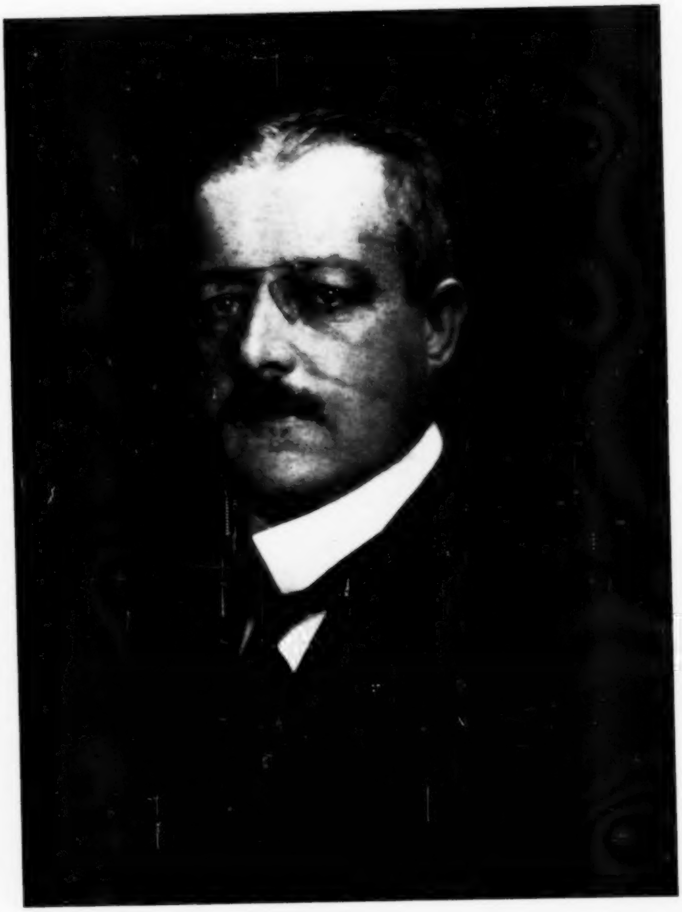
sik.

ten

nen

setz

ays
14.
ven
12.



Heinrich Ernst Albers-Schönberg